

HYDROGEOLOGICAL SURVEY OF PINE BLUFF ARSENAL

by

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PREFACE

This study was performed by personnel of the Geotechnical Laboratory (GL) of the U. S. Army Engineer Waterways Experiment Station. Funding for this study was authorized by Interagency Order (IAO) Nos. FJ7 P185901 FJQ6, FJ7 P187101 FJQ6, and FJ7 P1870 FJQ6 from Pine Bluff Arsenal (PBA), Pine Bluff, Arkansas, and IAO Nos. 6P241, 48-9-P140 M1-Q6, and 80-D-11 from the U. S. Army Toxic and Hazardous Materials Agency (USATHAMA) (formerly Project Manager for Chemical Demilitarization and Installation Restoration), Aberdeen Proving Ground, Maryland.

The field work was conducted during the periods 16 February to 4 August 1977 and 2-21 November 1978. Soil testing and data reduction were performed during 1978 and 1979 and report preparation was accomplished during the period February to August 1980. The drilling was performed by the Exploration Group, Engineering Geology and Rock Mechanics Division (EGRMD), GL, under the supervision of Mr. Jerald D. Broughton, Engineering Geology Applications Group (EGAG) of the EGRMD. The physical soil tests were performed by the Soil Testing Facility, GL. Personnel of EGAG accomplished the data compilation and analysis. Mr. Broughton prepared the report.

The study was conducted under the direct supervision of Mr. John H. Shamburger, Chief, EGAC, and under the general supervision of Dr. Don C. Banks, Chief, EGRMD, and Messrs. James P. Sale and Richard G. Ahlvin, Chief and Assistant Chief, GL, respectively.

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WORKING DRAFT

HYDROGEOLOGICAL SURVEY OF PINE BLUFF ARSENAL

PART I: INTRODUCTION

Background

Pine Bluff Arsenal (PBA) is located in Jefferson County, Arkansas, approximately 13 kilometres (km) northwest of the county seat, Pine Bluff, (see Figure 1), and approximately 48 km from Little Rock. The Arsenal is bounded on the east by the Arkansas River and on the west by the Missouri-Pacific Railroad. Industrial developments are to the south, and the northern perimeter is adjacent to woodlands and the National Center for Toxicological Research (NCTR). The PBA extends some 15 km in a northwest-southeast direction and is approximately 4 km wide. These 6000 hectares (ha) are used for administration, housing, and operations (80 ha); security and storage (790 ha); forest products (4430 ha); and primitive area preservation (700 ha) (Pinkham, C.F.A., et al, 1975).

The PBA was established in 1941 to manufacture, load, and assemble chemical and incendiary munitions. The initial mission involved magnesium and thermite types but was expanded to manufacture war gases and to fill chemical bombs, incendiary smoke munitions, and other munitions with chemicals such as chlorine, mustard, and lewisite. Subsequent operations have included the manufacturing, loading, and assembling of incendiary bombs, smoke grenades, smoke pots and canisters, white phosphorous, FS (sulfur trioxide chlorosulfonic acid solution), BZ (3-Quinuclidinyl Benzilate), and biological agents. Full-scale incendiary and chemical munitions operations were conducted during 1941-1945 and 1950-1953. The biological operations were conducted during 1953-1969; biological demilitarization was completed in 1972.

Limited operations were conducted at PBA during 1946-1949 and 1954 to the present. During portions of this time civilian contractors leased facilities for the manufacture of chlorine, DDT, malathion,

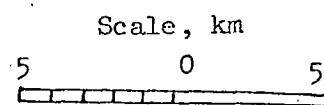
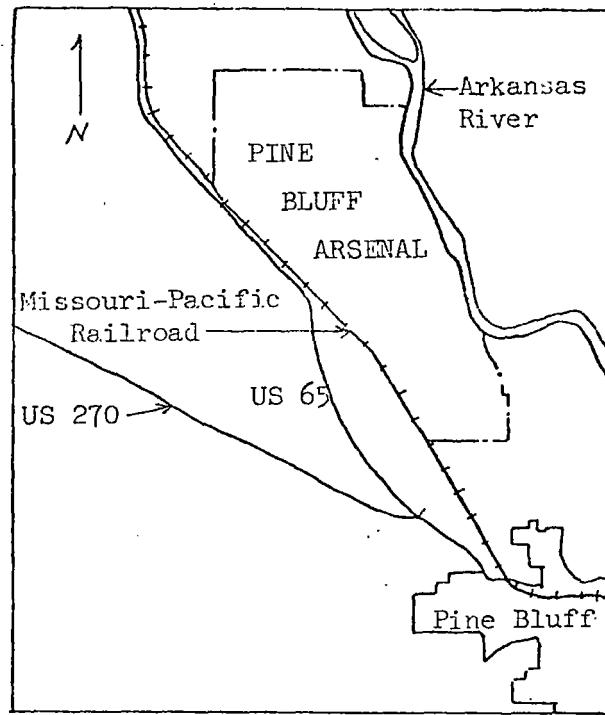


Figure 1. Location map for Pine Bluff Arsenal

parathion and chlorobenzenes (Pinkham, C.F.A., et al, 1975). Surface disposal of toxic materials was practiced during the Government and contractor operations which resulted in DDT, dyes, and incendiaries being spread on the surface at disposal sites.

Previous Studies

Groundwater contamination at other U. S. Army installations and knowledge of prior activities at PBA resulted in a data collection and analyses program to describe and define any contamination migration problems at the PBA. The first of these efforts (Lachapelle, David G., Brooks, Alan E., and Trescott, Edward B., 1969) was to locate, develop, and sample points to identify known locales of contamination or to establish baseline data to be used to compare future conditions. Table 1 and Table 2 show the multitude of materials used at the PBA and the materials and locations selected for monitoring, respectively. Figure 2 shows the locations of the monitoring wells for this study. Note that wells 1 and 2, in the vicinity of well 3, were not completed as monitoring wells and are not shown on the location map. This study concluded that the groundwater from wells 4 and 17 was contaminated because of their higher chemical oxygen demand (COD), sulfate, total and filterable residue, and chloride values; wells 5, 6, and 16 had phosphorous levels higher than those of the other wells; and wells 14, 15, and 17 had higher than average nitrate values. The study recommended that sampling be continued at these wells to provide the information required for diligent pollution control.

A survey conducted during 2-6 March 1970 by the U. S. Army Environmental Hygiene Agency (USAEEHA) addressed surface water contamination with domestic, solid, and industrial waste and found several perennial or intermittent streams carrying contaminants from all categories of waste. Untreated sewage, grease, white phosphorous, and film processing waste were being discharged into surface waters. Sample locations are shown on Figure 2. No reference was made to the potentiality of these contaminants

Page 6 removed-----see original.

entering the groundwater. The groundwater monitoring report (Lachapelle, et al, 1969) was quoted as determining that the only significant pollution was by chlorine at wells 4 and 17. The PBA was continuing the groundwater monitoring program.

The USAEHA conducted a groundwater and surface water monitoring program at the PBA in 1972 (USAEHA, 1973). This survey used the sampling points established during previous surveys. This survey identified contaminants in the groundwater (COD higher than 1968 baseline data) and surface water (suspended solids, phosphates, excessive biological oxygen demand and elemental phosphorous), but no phosphates were detected in the groundwater. Chlorine was found to be migrating from the northern area even though the contractor operations had ceased. The survey recommended that the surface waters be analyzed for lead, barium, and zinc because small quantities of these elements were used and were probably discharged on the ground surface. As recommended, PBA selected approximately 30 locations for detailed analysis of surface runoff, soils, and groundwater. Preliminary analysis was completed at several locations.

The Water Quality Geohydrologic Consultation (USAEHA, 1974) expressed specific interest in the shallow aquifer in the Quaternary terrace deposits. This aquifer was described as occurring at an elevation of 58-59 m above mean sea level averaging 12 metres (m) thick and having a permeability of 7.78×10^{-2} centimetres per second (cm/sec). Recharge was attributed to influent streams and groundwater movement was to the east. Increasing COD levels from the 1968 baseline data were concluded to be a significant contributor to pollution and recommendations were made for additional groundwater monitoring points, in the southeast portion of PBA, and additions and deletions to the suite of tests for potential contaminants. The groundwater sample points are shown on Figure 2.

A comprehensive survey (Pinkham, Carlos F.A., et al, 1975) conducted in 1972, addressed the geographic setting and physical characteristics of the PBA as background for wildlife descriptions and evaluations of soil, surface water and air pollution. This survey concluded that

surface waters were highly contaminated, surface soils were less contaminated, and air pollution was practically non-existent. These conclusions were based on the surface water quality monitoring sites and the contaminated surface soil sites shown on Figure 2. Groundwater was not considered in the environmental survey but the verified presence of contaminated areas of surface soil and water indicated a potential for the movement of contaminants through the subsurface to the groundwater.

A small portion of the north production area and the old sanitary land fill east of McCoy Road were known to be contaminated by DDT. Containment plans were generated by the PBA in April, 1975, and the USAEHA examined this plan and performed on-site inspections and tests during 28-31 July 1975. Based on these actions, a detailed containment program was recommended (USAEHA, 1976). A test boring in the north production area encountered a shallow water table and chemical analyses of soil samples revealed substantial DDT contamination. Based on these results, a monitoring system was recommended for the area which was to monitor four depths at six sites, but the system was never implemented. Figure 3 presents the lithologic log, DDT concentrations, permeabilities, and water table measurements from this report. The old landfill site was covered with a low permeability (7.41×10^{-7} cms) silt cap, and an impinging waterway was rerouted. No groundwater monitoring efforts were planned in this area, but continued evaluation of downstream surface waters was recommended. Surface sample sites are shown on Figure 2.

The U. S. Army Engineer Waterways Experiment Station (WES) performed a study to collect and review all data applicable to determine the potential of groundwater contamination (Broughton, Jerald D., 1977). Data generated by the U. S. Army Engineer Districts (Fort Worth, Little Rock, and Vicksburg), the PBA, the U. S. Geological Survey, the U. S. Soil Conservation Service, and the Arkansas Geological Commission were analyzed and the study concluded that the potential for groundwater contamination was present at PBA and a proposal to conduct a hydrogeological study to determine the extent of contamination was submitted to PBA as a part of the results of the literature study.

Sample Depth, Location ft 0	Lithology	DDT Concentration	Permeability
0	Black like fly ash w white modules.	353,000 ppm	
0	Stiff, yellow, sandy, silty clay.	303,000 ppm	
5	Yellow, grey, sandy, silty clay w red nodules which may be pieces of brick. Easily molded by hand.	7,350 ppm 911 ppm 1,180 ppm 8,790 ppm	
5	Soft, grey clay with red. Mettling makes ribbon easily.		6.9×10^{-8} cms
10	Water level 4 hrs after drilling		
10	Buff clay or silt layered with limonite. Hard in sampler, soft on auger.	606 ppm	
15	Hard, bluff clay with limonite layers.	250 ppm ND	2.7×10^{-7} cms
15	Water level 1 hr after drilling		
20	Med, hard, dark grey, fine sand.	ND	
20	Dark grey-green sand with layers of peat; crumbly.	ND	
25	Med grey sandy clay with thin bands of peat.		
30		12.2 ppm	8.1×10^{-6} cms

- Jar Sample
- Tube Sample
- ▽ Water Level

Figure 3. DDT Containment Program Boring

Purpose and Scope

The purpose of this study was to support the PBA efforts to determine if contaminants had reached the groundwater and if so, were they approaching the installation boundary or migrating off post. This determination required that the groundwater regime be identified in all geologic units to define the hydrogeologic characteristics of the aquifer(s).

The exploration and sampling were concentrated along PBA's boundaries and in proximity to known contaminated sources and included subsurface exploration, monitoring well installation, and physical tests on the soil samples.

The chemical evaluation of soil and water samples was conducted by the PBA and these results are not presented in this report.

PART II: PHYSICAL SETTING AND CLIMATE

Landforms

PBA is situated on three landforms: (1) floodplain of the Arkansas River, (2) an alluvial terrace, and (3) tertiary uplands. The local relief of the terrace is less than 20 ft, except along a few streams that have cut deeper than 20 ft. A 30- to 50-ft-high north-south trending bluff separates the floodplain from the terraces. Total relief on PBA is 150 ft from an elevation of 190 ft msl at the Arkansas River to an elevation of 340 ft msl in the northwestern portion (USAEHA, 1974). Plate 1 is a topographic map of PBA.

Geology

The PBA is within the Mississippi embayment, a 100,000-sq-mi, wedgeshaped portion of the Gulf Coastal Plain extending from its apex in southern Illinois to the Gulf of Mexico. The embayment is a southerly plunging syncline which is filled with sedimentary rocks and sediment ranging in age from Jurassic to Quaternary and reaching a maximum thickness of about 18,000 ft in the southern part of the region. The PBA is on the western flank of the embayment where approximately 4,000 ft of sediments overlie the Paleozoic bedrock. The Cretaceous system occupies the lower 3,000 ft and is overlain by about 1,000 ft of the Tertiary system which is important to the Hydrogeologic Survey of PBA. The Tertiary interval includes the Sparta Sand, an artesian aquifer which is a major source of water in the region. This aquifer is separated from the locally developed shallow aquifers in the terrace and alluvium by substantial thickness of low-permeability clay deposits. The majority of the clays are in the Jackson Formation which is not a source of water for the region (Cushing, E. M.; Boswell, E. H.; and Hosman, R. L., 1969). Figure 4 is a generalized stratigraphic column derived from

ERA	SYSTEM	SERIES	GROUP	FORMATION	
Cenozoic	Quaternary	Holocene	Alluvium	Alluvium	
		Pleistocene	Quaternary Terrace	Undifferentiated	
	Tertiary	Eocene	Jackson	Undifferentiated	
			Claiborne	Cockfield Cook Mountain Sparta Sand Cane River Carrizo Sand	
			Wilcox	Undifferentiated	
		Paleocene	Midway	Porters Creek Clayton	
		Gulf	Navarro	Arkadelphia Nacatoch	
	Mesozoic		Taylor	Saratoga Marlbrook Annona Ozan	
			Austin	Basal Detrital Unit Pre-Ozan	
Paleozoic	Cambrian through Pennsylvanian				
	Pre-Cambrian				

Figure 4. Generalized Stratigraphic Column for PBA

VTN (1975) and credited to Caplan, W. M. (1945) and Dunbar, C. O. and Wagge, K. M. (1969).

Quaternary deposits (meander belt deposits, alluvium, and terraces) dominate PBA except for the northwestern sector of the PBA which is blanketed by the older Tertiary age Jackson Group (Plate 2). The surface of the alluvium and meander belt deposits are primarily coarse grained, while the terrace and Jackson surfaces are composed of fine-grained soils (silts and clays).

Meander Belt Deposits

Meander belt deposits are developed within a floodplain during overbank flow and channel migration. At PBA the Arkansas River floodplain includes all lands between the Arkansas River and the escarpment bordering the Pleistocene Terrace--more specifically, those lands lying between the old channel which flowed through Yellow Lake and the Arkansas River. Meander belt deposits are alluvial in origin and include point bar deposits (ridges and swales) composed of alternating arcuate bands of the coarse-grained ridges and fine-grained swales, abandoned channels which are composed of fine-grained soil and natural levee deposits generally composed of silty sands and silts. The meander belt deposits at PBA are primarily poorly graded sand and some highly plastic clays. The sands are between Yellow Lake and the Arkansas River, and the clay deposits are concentrated along the old river channel and west to Yellow Bluff. Backswamp deposits are another environment of deposition within floodplains. These deposits are predominantly clay with varying amounts of organic material and occur between meander belts or meander belts and valley walls (escarpments). Backswamp deposits probably occur within the floodplain of the Arkansas River in PBA but have not been identified because a more detailed study would be required to depict them. For this study, if backswamp deposits occur, they are included in the meander belt deposits.

Recent Alluvium

Recent alluvium are those deposits laid down during comparatively recent geologic time by a stream or other body of running water as a

sorted or semisorted sediment in the bed of the stream or on its floodplain. The deposits can range from unconsolidated detrital material to clay. The alluvium depicted on Plate 2 is primarily silt and clay in the tributaries of the Arkansas River. The fine-grained nature of the source of these deposits is due to the source materials and the relatively low carrying capacity of the small streams at PBA.

Pleistocene Terrace

The Pleistocene terrace deposits occupy that portion of the PBA lying between the Jackson surface and the meander belt or alluvial deposits. The terrace is the result of rising and lowering of sea level during Pleistocene time. During a low still stand of the sea, the Jackson surface was eroded to an elevation approximating 100 ft in the vicinity of Pine Bluff by the ancient Arkansas River system. With the subsequent rise in sea level, an ancient Arkansas River deposited a thick sequence of gravels, sands, and silts, sandy silts or clays, in that order. This deposition stage was followed by a lowering of sea level which subjected this surface to erosion and subsequent reentrenchment of the Arkansas River to its current position. Cook (1966) named this surface the Hazlehurst Terrace from the type location in Hazlehurst, Georgia, and established elevation limits of 215 to 275 ft. These elevations correlate with the terrace at the PBA.

Soils

Surface soils at PBA range from clays, silts, silty sands to sands depending upon the environment of deposition. All of these soils may be encountered in the subsurface although the predominant soils are silts, sandy silts, and clays. The U. S. Department of Agriculture has mapped five soil associations on PBA. The Angie-Sacul (Saffel)-Savannah association, located on the northern end of PBA, is deep, moderately well drained, slowly and moderately slowly permeable, acid, and loamy soils. This soil association consists of the following series: 35 percent

Angie, 25 percent Sacul, 25 percent Savannah, and 15 percent inclusions of Amy, Ochlockonee, Iuka, Myatt, Cahaba, Susquehanna, and Pheba. Angie soils are a grayish-brown fine sandy loam surface soil overlying a yellowish-brown silty clay loam upper subsoil. Sacul soils consist of a grayish-brown fine sandy loam surface soil over yellowish-red or red clay subsoil that is mottled gray in the lower part. Savannah soils are a grayish-brown fine sandy loam surface soil over a yellowish-brown loam or sandy clay loam subsoil that has a gray, yellow, and brown mottled fragipan in the lower part.

The Cahaba-Savannah soil association occupies a small niche on the western boundary of PBA. This association is deep, well and moderately well drained, moderately and moderately slowly permeable, acid, and loamy and consists of the following soil series: 45 percent Cahaba, 40 percent Savannah, and 15 percent inclusions of Angie, Amy, Pheba, and Sacul. The well-drained Cahaba soils are grayish-brown or brown fine sandy loam surface soil over yellowish-red or red sandy loam or sandy clay loam subsoil. The moderately well-drained Savannah soils were described in the previous paragraph.

The Amy-Pheba-Savannah soil association occupies the central part of the Arsenal. These soils are deep, poorly to moderately well drained, slowly and moderately slowly permeable, acid, and loamy. This association consists of the following soil series: 45 percent Amy, 25 percent Pheba, 20 percent Savannah, and 10 percent inclusions of Myatt, Cahaba, Angie, Sacul, and Ochlockonee. The poorly drained Amy soils are gray silt loam surface soil over gray, mottled silt loam or silty clay loam subsoil. The somewhat poorly drained Pheba soils are dark gray to grayish-brown silt loam or loam subsoil with a fragipan in the lower part.

The Henry-Calloway-Grenada soil association occurs on the southern end of PBA. These soils are deep, poorly to moderately well drained, slowly permeable, level to gently sloping, acid, and loamy. This association is made up of the following soil series: 40 percent Henry, 40 percent

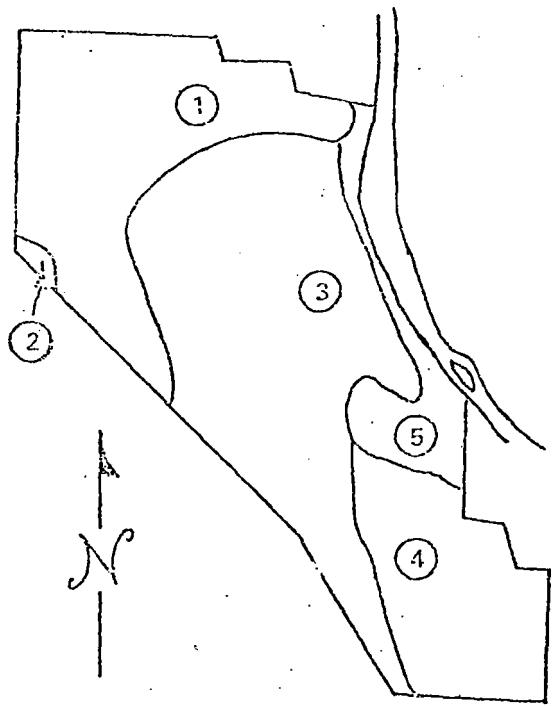
Calloway, 15 percent Grenada, and 5 percent inclusions of Falaya and Zachary soils, and gullied land. The poorly drained Henry soils are grayish-brown or gray silt loam surface soil over gray, mottled silt loam or silty clay subsoil that has a fragipan. The somewhat poorly drained Calloway soils are grayish-brown silt loam or silty clay loam subsoil with a fragipan. The moderately well drained Grenada soils are brown silt loam or silty clay loam upper subsoil and mottled gray and yellowish-brown lower subsoil that is a fragipan.

The Crevasse-Portland soil association occupies an area around Yellow Lake and a narrow strip running north along the east edge of the Arsenal. These soils are deep, somewhat poorly drained, rapidly to very slowly permeable, and acid to neutral in pH. The sandy and clayey bottom land soils are subject to frequent flooding. The association consists of the following soil series: 45 percent Crevasse, 30 percent Portland, and 25 percent inclusions of Rilla, Keo, Morgenfield, Latanier, Desha, and Perry. The excessively drained Crevasse soils are brown loamy sand surface soil overlying light yellowish-brown sand. The somewhat poorly drained Portland soils are dark grayish-brown silty clay loam to clay surface soil over dark brown to red, mottled clay subsoil.

Figure 5 is a generalization of the soil association distribution (Chemical Systems Laboratory, 1979). The U. S. Department of Agriculture divides soils into horizons. These horizons are identified as A, B, C, and D, which are defined as zones of humus accumulation and mineral leaching, mineral accumulation, unconsolidated or slightly altered parent material, and unaltered parent material, respectively. Plate 3 is a conversion of the USDA soil types (A horizon) to classification according to the Unified Soil Classification System (USCS).

Groundwater

The PBA is underlain by two aquifers that are widely used as a water supply. These aquifers are the Quaternary sands and gravels of



PINE BLUFF ARSENAL LEGEND:

- (1) ANGIE-SACUL (SAFFEL) - SAVANNAH
- (2) CAHABA-SAVANNAH
- (3) AMY-PHEBA-SAVANNAH
- (4) HENRY-CALLOWAY GRENADA
- (5) CREVASSE-PORTLAND

Figure 5. Soil associations at Pine Bluff Aresnal

the alluvium and terrace and the deeper Tertiary Sparta sand. The Quaternary aquifer is shallow (usually less than 50 ft deep) and is used in the surrounding areas for individual residence consumption, farm irrigation, and fish farming. Recharge is primarily by infiltration but along some reaches of the Arkansas River, the river is effluent to the aquifer. The PBA does not use this aquifer.

The Sparta sand is at depths of 800-1000 ft in the Pine Bluff area including PBA and ranges in thickness between 450-800 ft. The potentiometric surface occurs at depths of 200-250 ft (AEHA, 1974). The top of the Sparta sand lies at elevations ranging from 0 msl in the northwestern portion of Jefferson County to 900 ft below msl in the southeastern portion of the county. Wells in the Sparta produce some 50 million gallons per day for industry and municipal water supplies. Recharge is by infiltration in the outcrop area west of Jefferson County and by infiltration from the overlying Quaternary deposits north and southeast of Jefferson County (VTN, 1975). The Sparta sand is not hydraulically connected to the Quaternary aquifer at the PBA.

All of the Eocene (see Figure 4) formations below the Jackson Group have aquifers associated with them but the water demands of the Pine Bluff area have not required that these deeper formations be exploited. The remainder of the Tertiary (Paleocene) and all of the Cretaceous have no substantial aquifers and only occasionally does a formation have members which yield large quantities of water. Excessive mineralization also precludes using these deeper aquifers (Cushing, E. M., Boswell, E. H., and Hosman, R. L., 1964).

Climate

The PBA has temperatures ranging from a normal average low temperature of 44.2°F in January to a normal average high temperature of 83.2°F in July. The smooth transition from these extremes results in an average annual temperature of 64.2°F (VTN, 1975).

Approximately 50 in. of rainfall are spread over 100 days of measurable precipitation. This precipitation is scattered throughout

the year with monthly averages ranging from 3.5 in. during the fall to 4-5 in. during winter and spring. Snowfall is usually limited to 1-2 in. per year with many winters recording none. The potential evaporation, as measured with evaporation pans, is 58 in. per/year (VTN, 1975).

PART III: DATA COLLECTION

Field Exploration

The WES initiated a field drilling and sampling program in February 1977 as the initial phase of the hydrogeological study and completed the major portion of the sampling program in August 1977. A total of 108 borings were drilled during this phase. An additional four borings were drilled and sampled during November 1978 to approximate the total thickness and characteristics of the water bearing strata in the Pleistocene terrace. The purpose of the field exploration was to obtain soil samples for physical and chemical analysis and to collect water samples for chemical analysis. The PBA initiated, prepared, and monitored safety standard operating procedures and furnished all equipment and facilities as required during the drilling and sampling program. Plate 4 shows the boring locations of this program and the location of selected cross sections.

Sampling Procedures

Undisturbed and disturbed soil samples were acquired during the sampling program using a Mobil B-50 drill rig. All of the shallow borings were drilled using the hollow-stem auger technique. The deep borings (last four) were drilled with a Failing 1500 drill rig, and mud was used to preclude hole caving. An undisturbed sample is defined as a sample of minimal disturbance suitable for laboratory test. Undisturbed samples were obtained by pushing a thin-walled, 3-in.-diam, fixed piston sampler (Hvorslev) (see Figure 6) into the stratum being sampled. A 75 cm sample was retrieved from its position and the sample (Shelby) tube removed from the Hvorslev sampler head. The bottom of the tubed sample was examined to field classify the soil type and consistency, qualitatively describe the water content, and color according to the data management users guide (U. S. Army Chemical Systems Laboratory, 1977). The tube was then placed in an extruder and the upper 10-20 cm

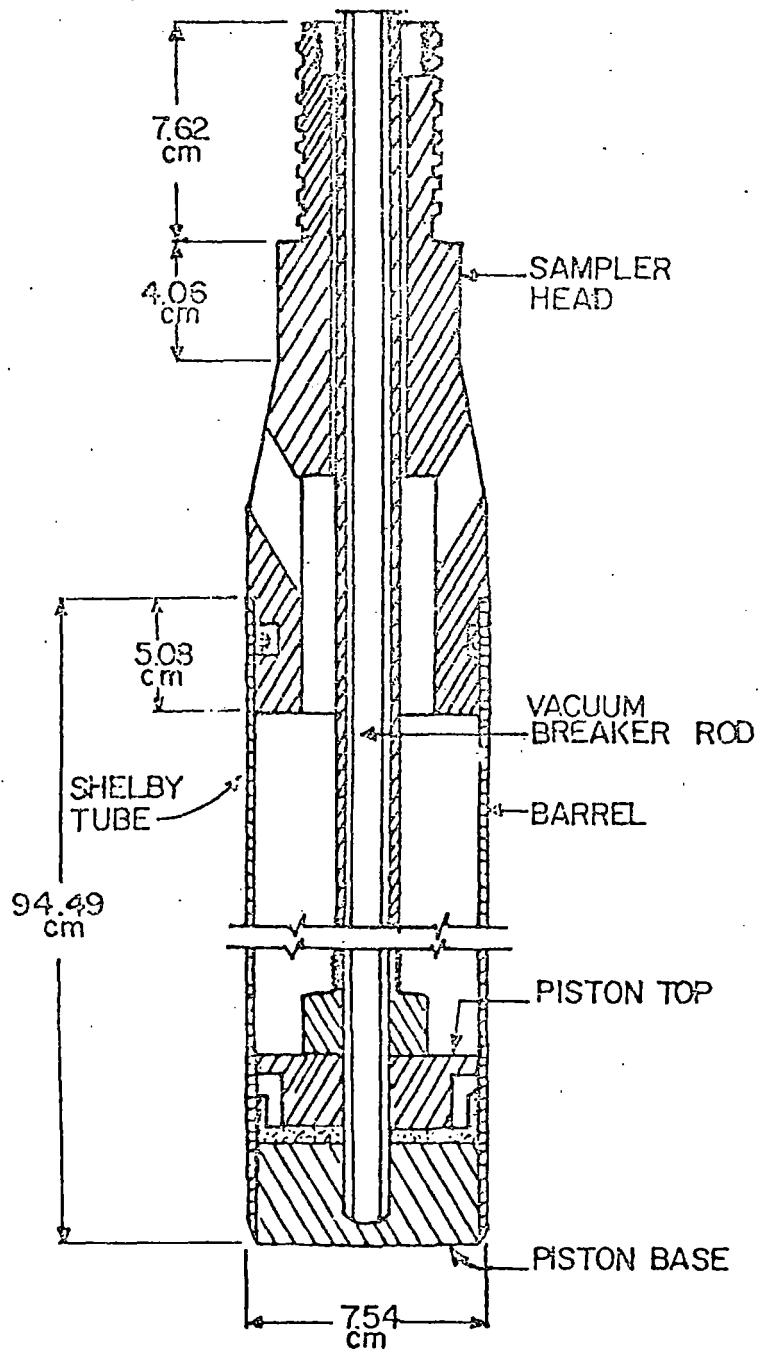


Figure 6. Sketch of Hvorslev Sampler

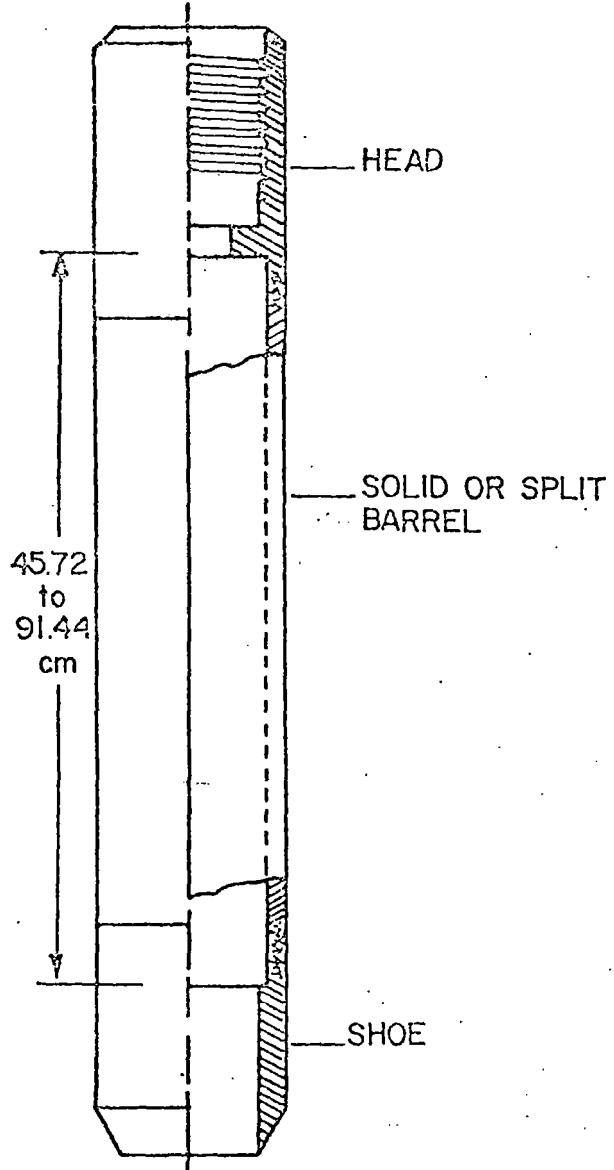
(amount was dependent on the total sample recovery, but in no case was a physical test specimen retained without a matching chemical test specimen) pushed out of the tube. The extruded portion was trimmed to remove any contaminant introduced by the sampling apparatus, examined to ascertain physical description, placed in a jar, and labeled for subsequent delivery to the PBA testing laboratory for chemical tests. Packers were inserted in each end of the sample tube and the tube labeled for storage at PBA for subsequent shipment to the WES for physical testing.

Disturbed soil samples were obtained with a 1.375-in. split-spoon sampler (see Figure 7) driven into the stratum being sampled by a 140-lb hammer with a 30-in. drop. A disturbed sample contains all the constituents of a particular stratum, but the original soil structure has been altered. These disturbed samples are sufficient for classification (Atterberg limits and sieve and hydrometer analysis), water content analysis, and chemical analysis.

Sampling Frequency

The sampling plan called for seven soil samples and one water sample to be taken at each boring location. The vertical distribution of the soil samples is shown in Figure 8. The position of the upper three samples was not varied from site to site but the lower four samples varied according to the estimated water table elevation. Sample 6 was positioned at the estimated water table, sample 7 three meters (m) below the water table, and samples 4 and 5 were evenly distributed between samples 3 and 6. Where the elevation of the water table was under-estimated, additional sample(s) were required and the vertical spacing was dependent on a revised on-site estimate of the water table. Usually a conservative estimate (high elevation) was made to preclude drilling past this sampling point and in no case was the sampling interval increased. On several occasions this method necessitated more than one additional sample.

Where the water table elevation was over estimated which was indicated by an increase in water content in sample 4 or 5, the next sampling interval was shortened to try and intersect the water table.



OD. 5.08cm, 6.35cm, 7.62cm, or 8.89cm
I.D. 3.81cm, 5.08cm, 6.35cm, or 7.62cm

Figure 7. Sketch of split spoon sampler.

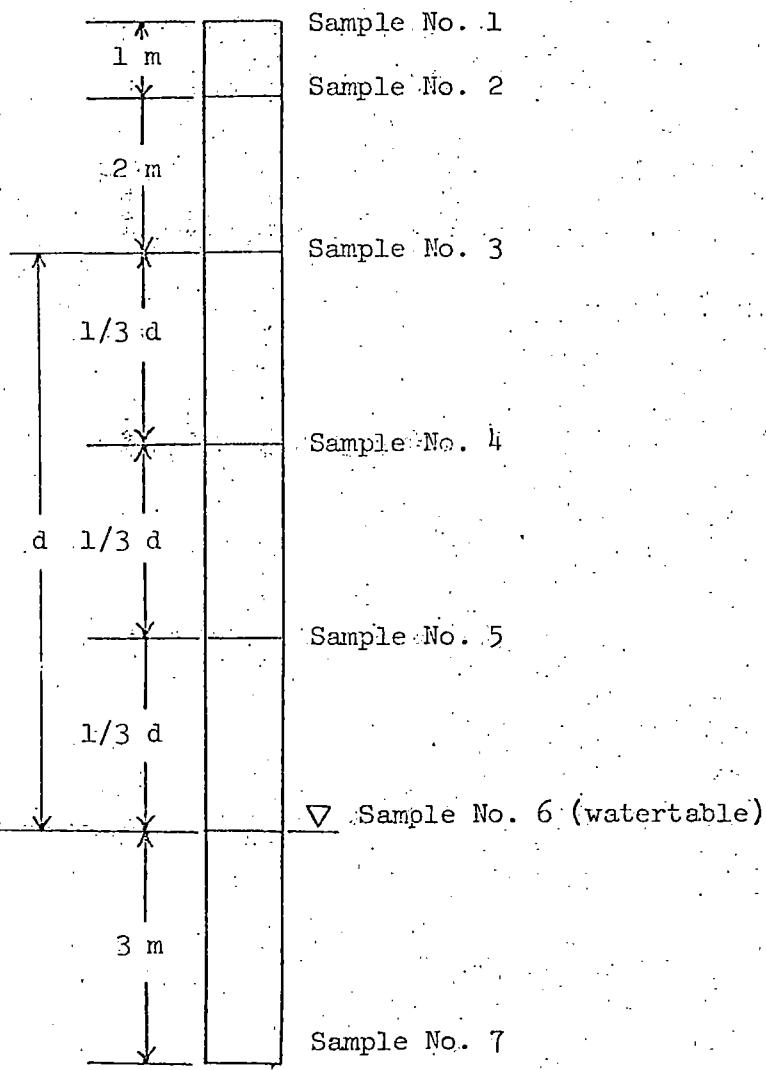


Figure 8. Vertical distribution of soil samples

Where the over estimation was discovered by saturated drill cuttings, drilling was halted and a sample was taken. The next sample was then taken 3 m below the water table.

Where the water table was estimated less than 6 m deep, a sampling interval of 1-1.5 m was assigned and the positions of samples 3-7 calculated accordingly. With extremely shallow water tables, fewer than seven samples were often obtained.

Immediately after obtaining the soil sample at groundwater intersection, a groundwater sample was obtained with a 2.54 cm, plastic bailer with a stainless steel foot valve. Figure 9 is a sketch of the bailer.

Sample Distribution

The soil samples were transported daily to a heated storage building and stacked to await shipment to WES. After the chemical scans were run by PBA and no hazardous or toxic materials were identified in the samples, the undisturbed samples were placed in specially constructed racks and transported to WES. The racks were cushioned to prevent shock and the sample tubes were pinned to prevent rotation and sample disturbance. The disturbed samples were transported in a manner to prevent breakage of the glass jars. When the samples arrived at WES they were stored with proper orientation in a controlled environment to await physical testing.

The soil samples for chemical scans were sealed in glass jars, labeled, and transported to controlled environment storage to await the tests. Water samples were placed in jars, labeled, and subsequently transported to the PBA testing facilities. Deviations from the above procedures were required with samples from sites that had a potential for white phosphorous contamination. In these cases the water samples were treated with a preservative and the water and soil samples were immediately transported to the testing facility at PBA.

Well Installation

After the last soil or water sample had been extracted at each boring location, the depth to the water table was determined for

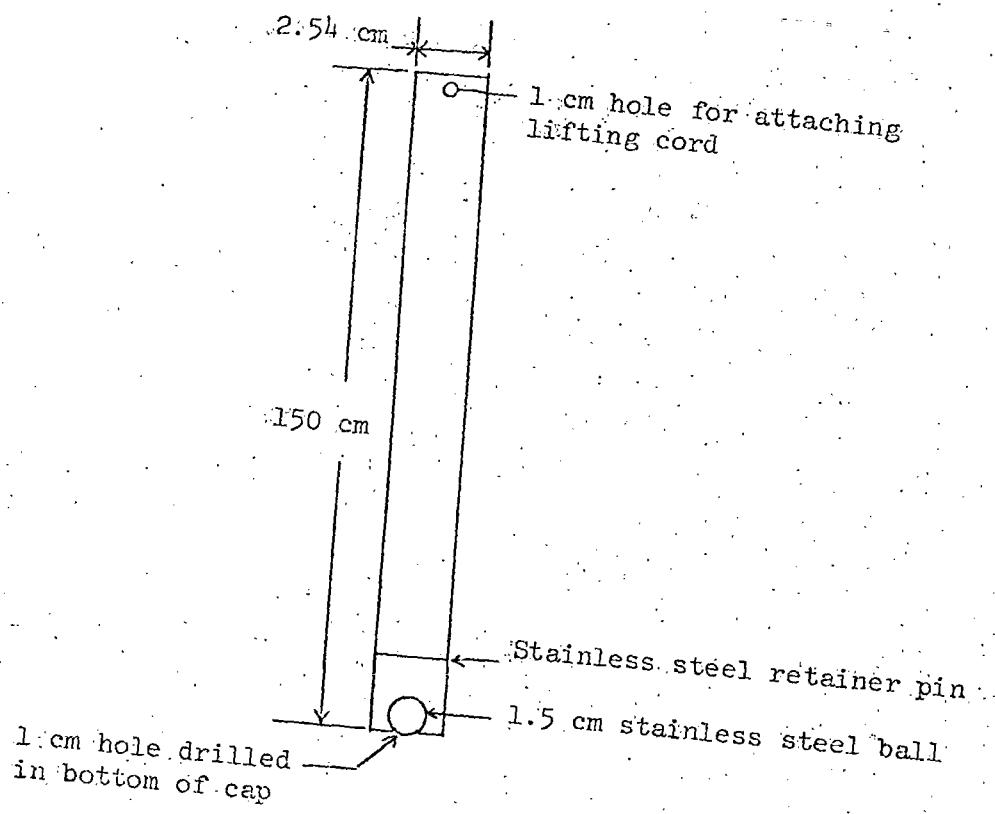


Figure 9. Section through bailer

placement of a monitoring well. In coarse-grained material the water table could usually be measured without any time lapse, but in fine-grained materials it was necessary to estimate the water level from the water content of the soil. After the depth of a monitoring well was determined, a well string was made up which consisted of (from bottom to top) an approximate 1.5 m section of capped, solid polyvinyl chloride (PVC) pipe, an approximate 1.5 m section of slotted PVC pipe, and a length of solid PVC pipe sufficient to rise approximately 1 m above the ground surface. Figure 10 shows a typical well installation. All joints were sealed to prevent any leakage above the screen. A 1 cm vent hole was drilled through the PVC approximately 10 cm below the top to permit equalization of pressures. A slip-on PVC cap was placed over the top of the well string.

The made-up well string was placed through the hollow-stem auger so the top of the well screen was at the water table. The hollow stem auger served as a casing to prevent collapse of the boring below the water table. When the well string was in place, the hollow-stem auger was removed. The riser (length of PVC pipe above the ground surface) was checked and adjusted if slippage either up or down had occurred. The annulus between the well string and boring wall was filled with washed river sand to a level approximately 1.5 m above the top of the screen. The remaining annulus was grouted using a water, cement, and bentonite grout (Figure 10). The bentonite was added to prevent shrinkage and cracking during the curing process. Voids caused by settlement of the grout were subsequently filled with a similar grout mixture. Each observation well was labeled and the bailer was suspended on the inside of each well. Appendix A contains measurements made for the stickup (STKUP), screen (SCREN), sand filter (SFILT), and grout (GROUT).

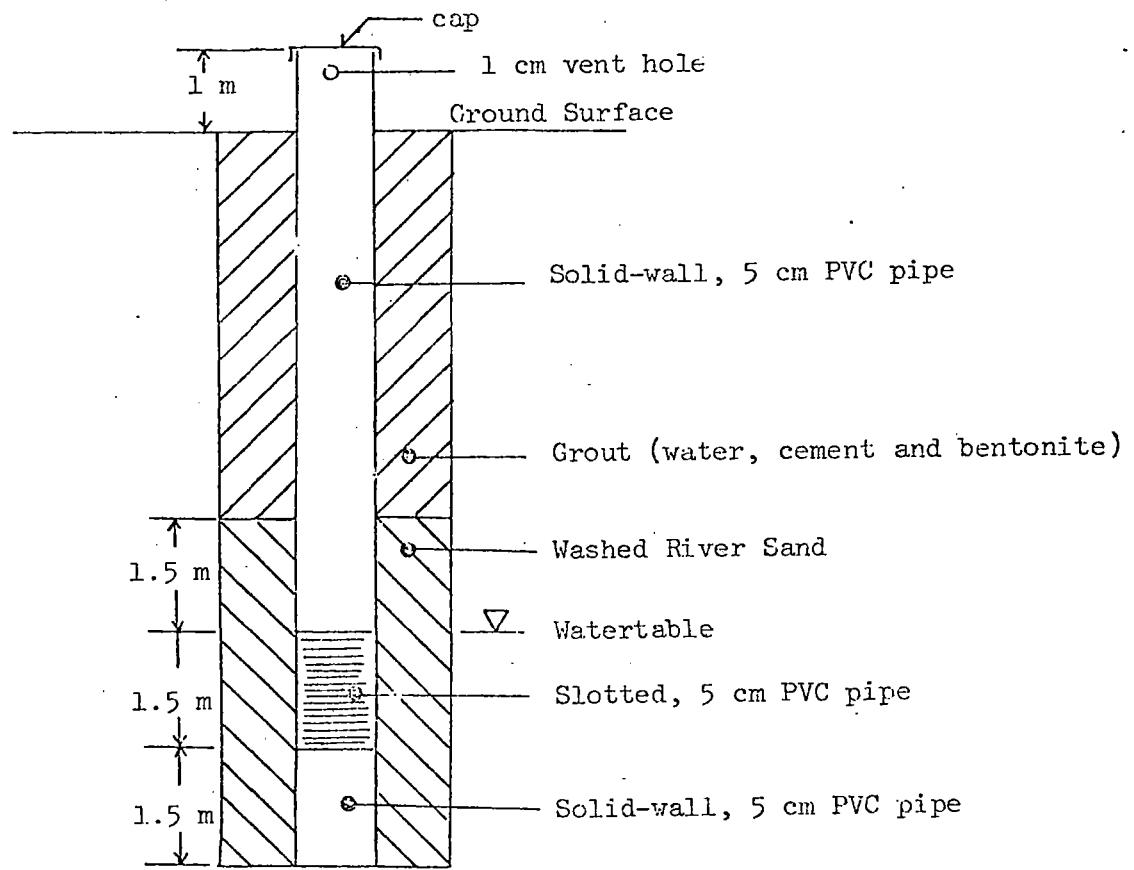


Figure 10. Section through typical well installation

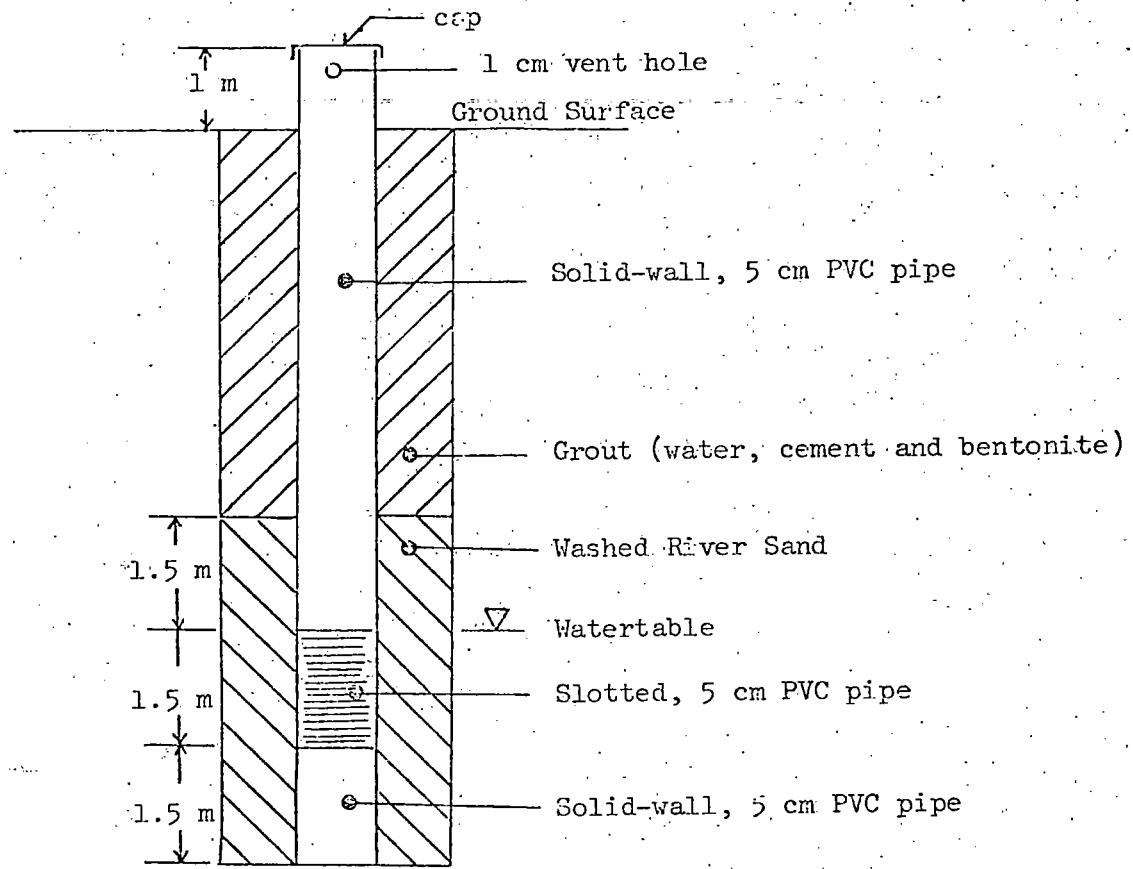


Figure 10. Section through typical well installation.

Physical Test

Standard soil test procedures as specified by Engineer Manual 1110-2-1906, "Laboratory Soil Testing," were followed during testing. Classification tests (Atterberg limits and grain-size distribution of the soils) were performed on all samples; water content and density tests were performed on selected samples; and permeability tests were usually performed on two samples per boring, one above and one below the water table. Detailed testing procedures are presented in Appendix B.

Classification of soils was made according to the USCS which depends upon grain-size distribution and the Atterberg limits. Grain-size distribution was determined with standard sieves and a hydrometer and the Atterberg limits (liquid and plastic limits) were determined with standard devices. The liquid and plastic limits are the water contents at the boundaries between the semiliquid and plastic state and the plastic and semisolid state, respectively. Figure 11 shows the USCS by which the PBA soil samples were described.

Water content (the amount of free water in a soil) and soil density (the weight per unit volume) are important engineering relationships and are useful correlations among samples for which a full suite of physical test data are not available.

Permeability is a measure of the soils ability to transmit water. Permeability tests were usually performed on two representative samples per boring which allowed meaningful correlations to be made among the various USCS types and general evaluation of the hydrogeological conditions of the PBA. The specimen above the water table was believed to be from the least permeable stratum between the surface and the water table. This material should furnish the most resistance to the downward migration of contaminants. The specimen below the water table was selected to furnish an approximation of the maximum rate of horizontal migration of contaminants.

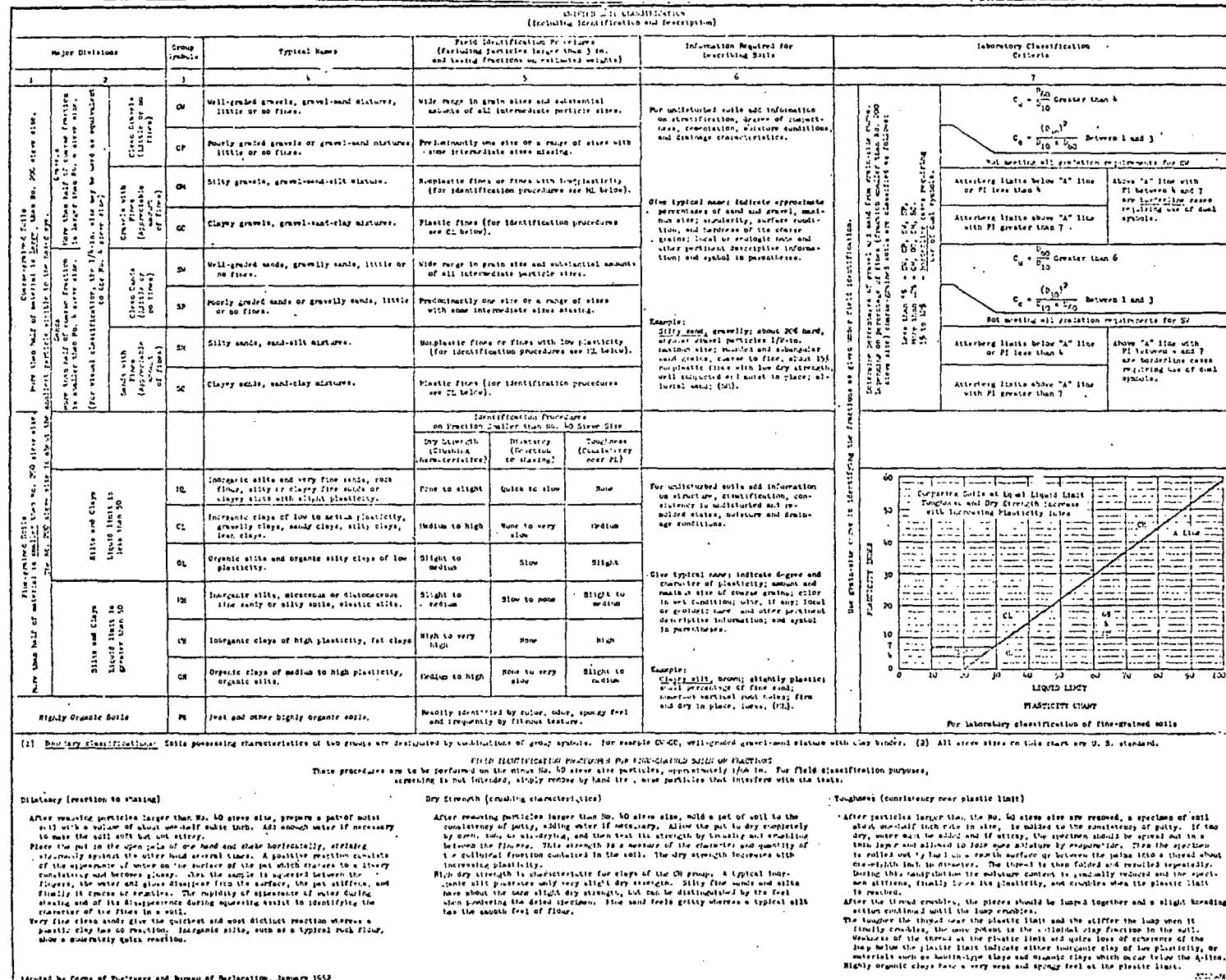


Figure 11. Unified Soil Classification System

PART IV: STUDY RESULTS

Soil Characteristics

Classification

Of the 782 samples tested, the fine-grained material predominates with 572 samples being classified as silt and clay (Figure 11). The clays are further subdivided into two groups, L and H, according to the liquid limits of the material. In these groups the symbol C stands for clay, with L and H denoting low or high liquid limits, with the dividing line set at a liquid limit of 50. The soils are primarily inorganic clays. Low plasticity clays are classified as CL and are usually lean, sandy, or silty clays. The medium and high plasticity clays are classified as CH; these include the fat clays, gumbo clays, and some volcanic clays. Three hundred and twenty-four samples were classified CL and 132 samples were classified as CH.

The silts are also further subdivided into two groups according to the liquid limits of the material (Figure 11). In these groups the symbol M has been used to designate predominantly silty materials. The symbols L and H represent low and high liquid limits, respectively, and dividing line between the two is set at a liquid limit of 50. The soils in the ML and MH groups are sandy, clayey, or inorganic silts with relatively low plasticity including loess-type soils and rock flours. Seventy-two of the samples were classified as ML and nine of the samples were classified as MH.

Soils with liquid limits and plasticity indexes falling within the hatched zone of the classification chart are assigned a dual classification, CL-ML; 35 of the samples classified were within this zone (Figure 11).

The coarse-grained material was dominated by silty sands (SM). This classification covers sands with between 12 and 50 percent of the sample passing the No. 200 sieve (smaller than .074 mm) and the plasticity index and liquid limit of the materials passing the No. 40 sieve.

(smaller than 0.42 mm) plot below the "A" line on the plasticity chart (Figure 11). One hundred and two samples were classified as SM.

Forty-five samples were classified as poorly graded sands which contain little or no plastic fines (less than 5 percent passing the No. 200 sieve). This material, SP, is called poorly graded because the sand grains fall within a narrow size range.

Fifty-three samples were classified as borderline cases between the SP and SM and received a designation of SP-SM. This group has between 5 and 12 percent of the material passing the No. 200 sieve.

Nine samples were classified as clayey sand (SC). This is a sandy soil with between 12 and 50 percent fairly high plasticity material passing the No. 200 sieve. The liquid limit and plasticity index plot above the "A" line on the plasticity chart (Figure 11).

One sample received dual classification of SC-SM. This material has between 12 and 50 percent passing the No. 200 sieve and the liquid limits and plastic limit of the sample plots within the hatched area of the classification (Figure 11).

The predominance of fine-grained material is attributed to the majority of the samples being obtained within the fine-grained upper strata of the terrace material and the finer grained material in the Jackson undifferentiated.

The liquid limits of the fine-grained material ranged from 21 to 87 percent water with the 25-35 percent water range predominating. The plastic limits of the fine-grained material ranged from 10 to 34 percent water with the 15-20 percent water range predominating. Plates 5-10 are cross sections along selected traverses (Plate 4) and the soil types are based on the physical analyses of the soil samples.

Water Content and Density

Water contents ranged from 2.9 to 40.6 percent with 15 to 25 percent occurring most often. The accompanying densities ranged from 1.21 to 1.45 grams per cubic centimetre (g/cc) with the range of 1.4 g/cc to 1.7 g/cc being predominant.

Permeability

The permeabilities ranged from 0.0 cm/sec to 2.0 cm/sec. The majority of the coarse-grained materials (SP, SP-SM, SM, SC, and SC-SM) exhibited permeabilities in the range of 1×10^{-3} to 1×10^{-5} cm/sec. The fine-grained materials (ML, MH, CL-ML, CL, and CH) usually exhibited permeabilities in the range of 1×10^{-5} to 1×10^{-8} cm/sec. Permeability distribution according to the USCS types is shown in Table 3.

Figures 12 and 13 show the distribution within soil types for the coarse-grained and fine-grained soils, respectively. Table 4 presents the results of all physical tests.

Water Levels

Water level measurements were made on a number of occasions but only one complete round was made with the specific purpose of obtaining a set within a short time frame. This set of measurements was made during 2-4 August 1977 and these elevations are shown in Table 5 along with the next most concise data set; those taken during 24 June - 29 July 1977, a period of well development and drilling operations. Plates 11 and 12 are water table maps based on these measurements. Appendix A contains the stabilized groundwater measurements made during this study.

Subsurface Cross Sections

Subsurface cross sections (Plates 5-10) were constructed to show the near-surface (<2 metres) distribution of USCS soil types along the selected traverses at PBA. These traverses were selected to cross the different geologic formations and the major concentrations of known surface contamination (see Plate 4 for cross section locations). A discussion of each cross section is presented in the following paragraphs.

Section A-A' is along the western boundary of the PBA and crosses the Jackson Group and the Pleistocene terrace deposits. A predominance

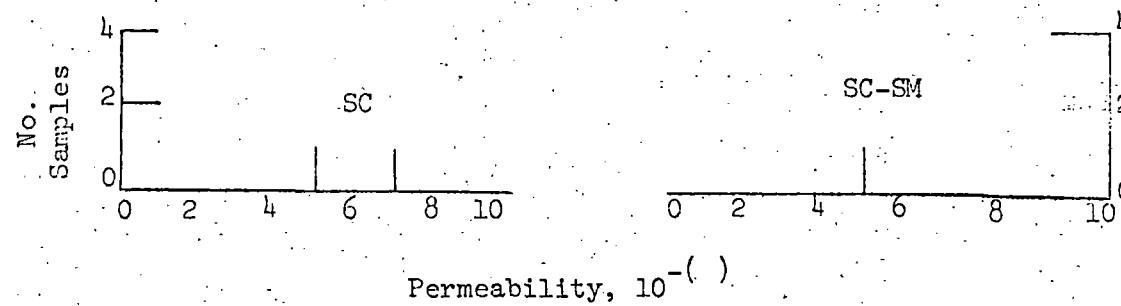
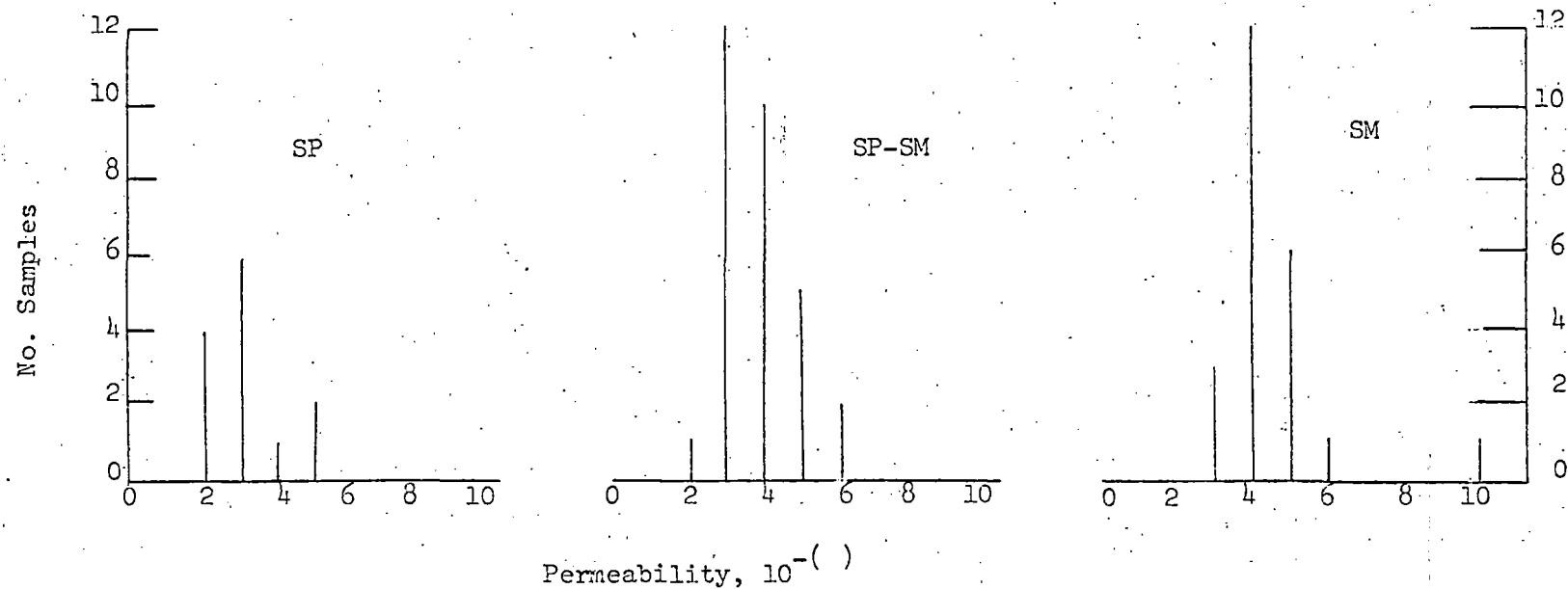


Figure 12. Distribution of Permeabilities
in Coarse-Grained Soils

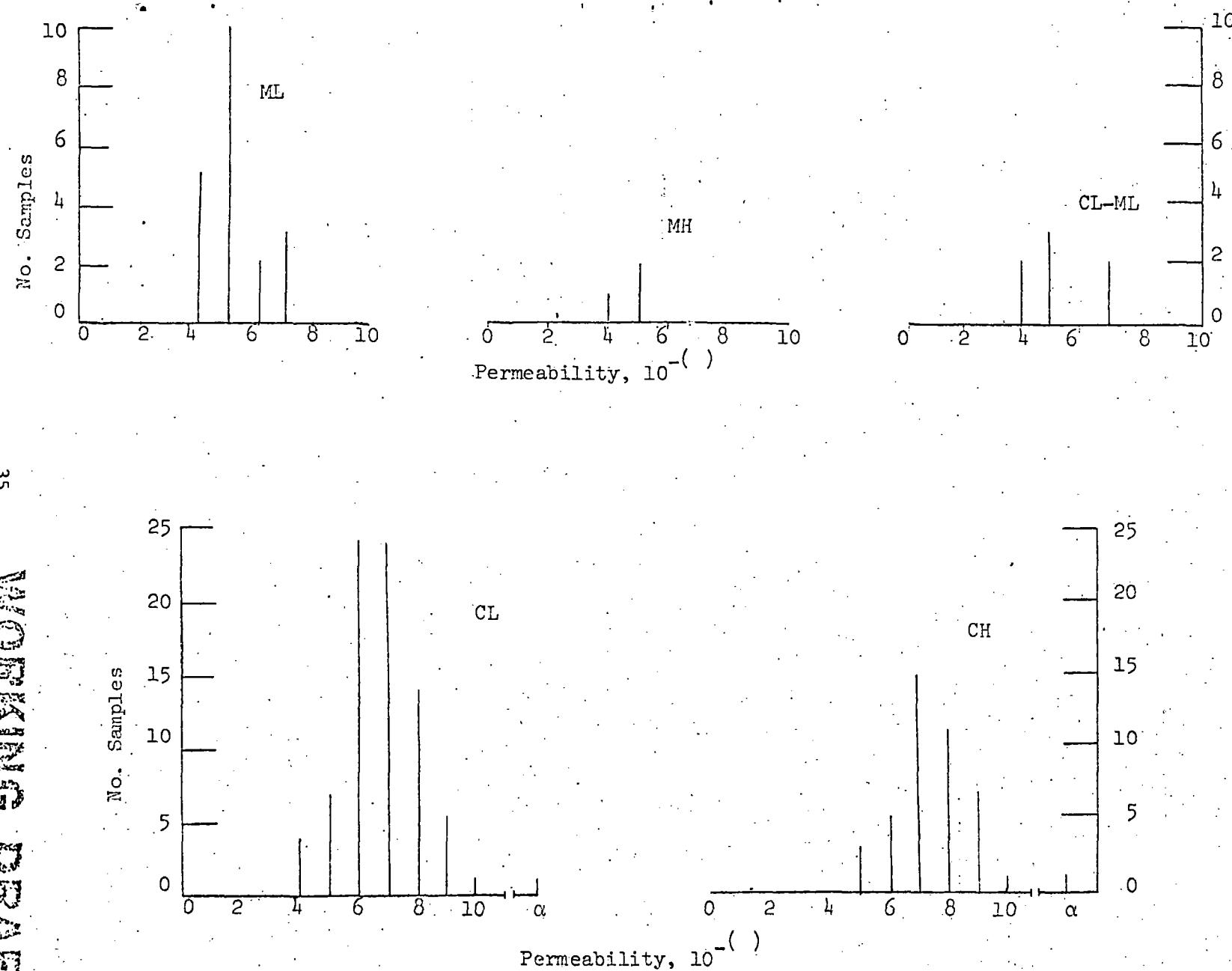


Figure 13. Distribution of Permeabilities
in Fine-Grained Soils

of fine-grained material, i.e. silts (ML and MH) and clays (CL and CH) is apparent. Boring No. 89 is along side an intermittent stream and shows the effect that drainageways have on the water table in the Jackson Group. In contrast, the water table in a larger stream dissecting the terrace is at about the same elevation.

Section B-B' is along the northern boundary of the PBA and NCTR. This traverse crosses the Jackson Group, the terrace, and the meander belt deposits. One boring (No. 94) is in a small creek and has a veneer of coarse-grained material while two borings (Nos. 97 and 99) are on a terrace remnant. The water table exhibits the usual steep gradient in the higher, fine-grained deposits of the Jackson Group and a shallow gradient in the coarser-grained meander belt deposits.

Section C-C' is along the eastern boundary of the PBA and borders the Arkansas River in the northern sector (boring No. 102 to boring No. 8). This section crosses meander belt deposits in the north and Pleistocene Terrace deposits in the south. A melange of coarse-grained and fine-grained deposits characterize the surface of the meander belt deposits and the surficial terrace deposits are fine-grained. The water table shows little variation along this section. This relatively constant level is attributed to the position of the section (perpendicular to general water table gradient) and the proximity of the Arkansas River.

Section D-D' is in the northern portion of the PBA and crosses the DDT area. This section traverses the Jackson Group deposits and the Pleistocene Terrace before dipping down to meander belt deposits at boring No. 52. Fine-grained deposits are present in the Jackson Group and the surficial deposits of both the terrace and meander belt deposits are fine-grained. An elevated, steeply sloping water table is shown in the fine-grained Jackson Group in contrast to water table in the terrace and meander belt deposits which exhibits a nearly flat-lying, lower water table. The higher elevation and steeper gradient in the Jackson Group are due to the higher surface elevation and lower permeabilities of the Jackson Group.

Section E-E' is in the south-central portion of the PBA and crosses terrace deposits and meander belt deposits. The section extends from the western boundary (boring No. 75), passes the head of White Creek and south of the old sanitary landfill, and terminates on the eastern boundary with fine-grained meander belt deposits (boring No. 31). This entire section is predominantly fine-grained deposits. Boring No. 75 (western end) shows an elevated water table which is probably due to the proximity of the Jackson Group deposits but the remainder of the section shows the characteristic low gradient and deeper water table of the terrace and meander belt deposits.

Section F-F' traverses the central portion of the PBA in a generally north-south direction. It crosses deposits of the Jackson Group, Pleistocene Terrace, and Recent alluvium. This section passes through the DDT area and skirts the northern perimeter of the old sanitary landfill before terminating on the southern boundary at boring No. 58. Fine-grained surficial deposits of the Jackson Group and Pleistocene Terrace predominate the section and the usual elevated water table of the Jackson Group and the flat-lying lower water table of the terrace aquifer is present. The single alluvium boring (No. 6) has a series of coarse-grained and fine-grained deposits and the water table closely approximates the surface water level of the adjoining creek which is a tributary of the Arkansas River.

Vertical Migration of Contaminants

Vertical migration of contaminants is governed by the solubility of the contaminant, the permeability of the soil, and the driving force or hydraulic head applied to the solution. This head may be provided either by contaminated liquid or rainfall. At the PBA, both of these conditions could be met. To combat vertical migration, deny the contaminant to the environment and/or enhance the factors which decrease permeability of the soil and/or the hydraulic head. These are practiced

at PBA by cessation of surface or subsurface disposal of contaminants and the covering of contaminated areas with low permeability soils. The susceptibility of the PBA to problems with vertical migration depends on the surface materials which contaminants come in contact.

The presence of coarse-grained soils (Plates 2 and 3) in alluvial deposits and terraces have potential for vertical movement of contaminants from the surface to the water table aquifer. However, the potential is reduced by the presence of a hardpan at shallow depths (1-2 m) over most of the PBA. The terrace surface material consisting primarily of silts and silty sands is underlain by finer-grained materials (clays at a depth of 1-2 m), which should retard the vertical migration to depth. The only area of the PBA subject to rapid infiltration and percolation to the water table is the Arkansas River floodplain. This area was mapped as meander belt deposits on the geology map and silty sand on the soils map. Several borings in this area (8, 9, 49, 51, 52, and 79) show the predominance of coarse-grained materials from ground surface to the water table (see Plate 8). The predominance of fine-grained surface soils on the cross sections presented on Plates 5, 6, 8, 9, and 10 should retard vertical migration on the terrace and Jackson Group. The predominance of coarse-grained deposits in the meander belt deposits offer virtually no resistance to migration between the ground surface and the water table.

Subsurface Horizontal Migration of Contaminants

The potential for subsurface horizontal migration of contaminants is dependent upon the contaminants reaching into the groundwater. After entering the groundwater, the rate of horizontal contaminant migration is dependent upon the permeability of the aquifer and the driving force or hydraulic head.

The water table maps show two distinct groundwater gradients, both moving to the east. The Quaternary surface (see Plate 2) is underlain

by a water table which approximates river level and dips gently toward the river. Water table in the Jackson Group slopes rather sharply to the east and lies at a higher elevation than in the Quaternary. While the water table maps show a continuous, one directional groundwater basin (easterly) flow covering the entire PBA, it is probable that due to surface elevation differences within the Jackson, the groundwater in the northwestern portions of the PBA is feeding the stream in the adjacent alluvium. However, the prime objective of this study was to define off-post flow which is to the east. Some of the water levels in the northwest sector closely approximate the surface flow levels in the topographic lows before joining the general trends of flow to the east. The intricacies (Plates 5 and 6) of groundwater flow in the northwest sector are not relevant.

The higher gradients in the Jackson Group (Plates 5, 6, and 8) are not interpreted as indicating either a greater velocity or larger volume than the lower gradients in the Pleistocene Terrace, meander belt deposits, or alluvium. This is the result of the thinner, discontinuous, lower permeability saturated zones of the Jackson Group as compared to the other deposits.

Total mass flow passing beneath the PBA cannot be calculated due to the lack of data on the total saturated thickness of the aquifer. An estimate of groundwater velocity may be obtained from the equation:

$$v = \frac{ki}{p}$$

where v = groundwater velocity

k = permeability

i = hydraulic gradient

p = porosity

Using the general values of:

k = .01 cm/sec in the terrace and meander belt deposits

k = .0001 in the Jackson Group

i = .0008 in the terrace and meander belt deposits.

$i = .007$ in the Jackson Group

$p = .3$ for all deposits

Solving for velocity gives values of 84 m/yr in the terrace and floodplain and 70 m/yr in the Jackson Group. These values are probably in the right order of magnitude but site specific data would be required for precise estimates.

Surface Storage of Hazardous Waste

Safe storage of hazardous or toxic waste requires detailed planning, precise execution, and scrupulous monitoring. Because of the potential for vertical and horizontal subsurface migration of contaminants at PBA, any contaminant storage must be properly planned and monitored. Detailed site specific investigations will be required at any candidate storage site to define the strata between the ground surface and the water table as well as the gradient and hydraulic conductivity of the water table aquifer. In the absence of a verifiable, thick, low permeability strata, site enhancement procedures will be required. Site preparation may range from simply mixing an extremely low permeable material in the final surface of the storage area to placing an impermeable base of cement, asphalt, membranes, chemical additive, etc. Requirements for a storage site must also include provisions for a system to prevent surface water (rainfall runoff) from coming in contact with the materials and installing a groundwater monitoring system by placing a network of wells around the site. The hydrogeologic characteristics of the Jackson Group deposits are more suitable for a storage site than the Pleistocene Terrace. However, the procedures discussed above for site preparation must be followed regardless of the location. The floodplain should be completely eliminated from any consideration.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The potential for the vertical migration of contaminants to the water table and the subsequent easterly movement of these contaminants off-post exists at the PBA. That portion of PBA occupied by the Jackson Group sediments is least susceptible to the vertical migration; the Pleistocene Terrace is the next most resistant; and the meander belt deposits and alluvium are very susceptible to the vertical migration of contaminants. The Pleistocene Terrace, the meander belt deposits, and the alluvium are very susceptible to the horizontal migration of contaminants after entering the groundwater. The Jackson Group of sediments offer some resistance to the horizontal migration of contaminants because of their fine-grained characteristics.

The Jackson Group sediments contain the best candidate sites to securely store any soluble toxic material. This surface at a proposed storage site will require extensive site investigation and probably substantial engineering improvements. However, detailed investigations and appropriate engineering improvements should make limited storage feasible. The Quaternary surface of PBA will require extensive engineering effort to securely store any soluble toxic material. Even these improvements should be limited to the higher elevations of the terrace surface. The floodplain of the Arkansas River should not be considered.

Recommendations

The monitoring wells installed during this study can furnish an understanding of the groundwater regime of the PBA and aid in evaluating the chemistry of the groundwater through a systematic water level measurement and water sampling and analysis program. Groundwater measurements and sampling should be made on a monthly basis for at least a year to

establish trends and then quarterly to verify the trends. Subsequent years should have measurements made at the time of maximum and minimum groundwater elevations as established during the first two years.

Additional monitoring points are not recommended at present but may be required to refine the definition of the groundwater regime in critical areas or to verify any contaminant movement should chemical analyses indicate the presence of contaminants. The location of these additional monitoring points should be determined by a careful analysis of the hydrogeology and groundwater chemistry of the area in question.

Table 1
Materials Used in PBA Operations

Acetone, ketones	Magnesium hydroxide
Agar - Agar	Magnesium powder
Alcohols, solvents	Metal powders
Aluminum, powder, or grained	Nitrates (inorganic)
Animal protein	Nitrocellulose (wet)
Barium chromate	Perchlorates
Barium nitrate	Phosphorus, red
BZ	Phosphorus, white
Calcium carbonate	Plant protein
Caustic	Potassium bicarbonate
Cellulose nitrate-camphor	Potassium chlorate
Cellulose nitrate	Potassium nitrate
Charcoal	Protamine sulphate
Chloracetophenone (CN)	Quaternary ammonium compound (50% solution)
Chlorates	Raffinose
Chlorine	Resin
Chromates	Silicone
CS	Silicone antifoams
Cysteine HCl	Skim milk solids
Dextrine	Soda, sodium bicarbonate
Dextrose	Sodium chloride
Diatomaceous earth	Sodium nitrate
Dipyridyl	Sodium sulfate
Dye, green	Sucrose
Dye, red	Sugar, powdered
Dye, yellow	Sulphur
Fuller's earth	Sulfuric acid
Glycene	Thermit
Graphite	Thiamine HCl
Hexachlorethane	Thiourea
Hydrochloric acid	Titanium, powdered
Iron oxide	Tricalcium phosphate
Lactose	Tryptose
Lard oil	Zinc borate
Lead oxide (red lead)	Zinc oxide
Magnesium carbonate	

Table 2
Schedule of Monitoring Wells

<u>Well number*</u>	<u>Manufacturing area monitored</u>	<u>Location</u>
1a/	Chlorine**	Near building 54-360 acetylene generator
2b/	Chlorine**	Between buildings 53-810 and 50-910
3c/	Chlorine**	Between buildings 53-110 and 53-220
4	Storage depot	Webster Road
5R	WP	Near creek receiving WP plant waste
6	WP	Near WP waste system
7	HC	Off Stokes Road near Avenue 34-B
8	HC	On Stokes Road
9	Smokes	338 Street near Avenue 331-A
10	Smokes	Near building 33-670
11	BZ	Avenue 321-A
12	BZ	Near building 32-690
13	CN, CS	Avenue 311-A near building 31-570
14	CN, CS	Building 31-830 and building 31-840
15	CN, CS	Avenue 311-B and 310 Street
16R	HC	Sibert Road
17R	Contaminated ditch near McCoy Road	

* R = Existing wells rehabilitated.

** ARKLA Chemical Co.

a/ Drilled to depth of 135 feet without evidence of water. Abandoned as a dry hole.

b/ Drilled to depth in excess of 100 feet. Abandoned as a dry hole.

c/ Drilled to 685 feet to reach water. This was done by PBA in an attempt to prove the absence of useful groundwater for monitoring in the area of the leased chemical facility.

Table 3
Distribution of Permeabilities According to Soil Types

<u>Soil Type (USCS)</u>	<u>Permeability, cm/sec</u>				<u>No. Samples</u>
	<u>Maximum</u>	<u>Minimum</u>	<u>Mean</u>	<u>Average</u>	
SP	2.00×10^{-2}	5.30×10^{-5}	5.60×10^{-3}	6.63×10^{-3}	13
SP-SM	1.50×10^{-2}	3.50×10^{-6}	5.85×10^{-4}	1.97×10^{-3}	20
SM	8.30×10^{-3}	6.90×10^{-10}	3.80×10^{-4}	7.39×10^{-4}	23
SC-SM	1.48×10^{-5}	1.48×10^{-5}	1.48×10^{-5}	1.48×10^{-5}	1
SC	2.74×10^{-5}	5.44×10^{-7}	1.40×10^{-5}	1.40×10^{-5}	2
ML	6.90×10^{-4}	1.03×10^{-7}	3.00×10^{-5}	1.22×10^{-4}	20
MH	1.30×10^{-4}	1.20×10^{-5}	3.00×10^{-5}	5.73×10^{-5}	3
CL-ML	2.30×10^{-4}	1.90×10^{-7}	2.40×10^{-5}	6.50×10^{-5}	7
CL	1.40×10^{-4}	0.00	8.30×10^{-7}	8.09×10^{-6}	79
CH	6.20×10^{-5}	0.00	1.20×10^{-7}	2.71×10^{-6}	43

Table 4. Physical Test Results.

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
1	29-67	22.0	16.0	CL-ML			
1	124-174	21.0	17.0	SM			
1	324-347	NP	NP	SM			
1	599-648	31.0	16.0	CL			
1	874-918	32.0	17.0	CL	20.7	1.67	
1	1174-1184	26.0	19.0	CL	24.6	1.57	2.3×10^{-7}
1	1449-1500	NP	NP	SP-SM		1.60	1.9×10^{-3}
2	24-70	26.0	18.0	CL			
2	124-160	38.0	17.0	CL			
2	324-373	29.0	18.0	CL			
2	619-665	32.0	12.0	CL			
2	914-947	32.0	15.0	CL			
2	1209-1233	55.0	20.0	CH	21.5	1.67	
2	1509-1543	29.0	17.0	CL	27.9	1.51	2.2×10^{-7}
3	29-70	43.0	16.0	CL			
3	179-225	30.0	18.0	CL	10.4	1.67	7.7×10^{-6}
3	329-375	22.0	15.0	CL	7.5	1.90	9.8×10^{-8}
3	629-675	51.0	16.0	CH			
3	779-824	26.0	12.0	CL			
3	929-974	32.0	17.0	CL			
3	1079-1124	NP	NP	ML			
3	1229-1268	NP	NP	SP			
3	1679-1720	NP	NP	SP-SM		1.67	4.0×10^{-6}
4	29-75	23.0	16.0	CL-ML			
4	129-170	30.0	16.0	CL	22.2	1.58	
4	325-371	37.0	14.0	CL			
4	646-692	29.0	15.0	CL			
4	963-995	NP	NP	ML			
4	1275-1325	NP	NP	SM	15.4	1.68	3.3×10^{-5}
4	1570-1615	NP	NP	SP		1.63	5.3×10^{-7}
5	75-145	43.0	18.0	CL	30.4	1.46	3.8×10^{-7}
5	179-224	60.0	23.0	CH	39.8	1.23	1.2×10^{-3}
5	389-435	NP	NP	SP-SM		1.58	3.2×10^{-3}
6	24-61	NP	NP	SM			
6	124-170	NP	NP	SM			
6	224-275	61.0	24.0	CH	35.7	1.27	
6	399-425	NP	NP	SP	24.2	1.47	1.2×10^{-2}
6	604-655	68.0	23.0	CH	40.6	1.25	7.5×10^{-8}
7	24-74	22.0	16.0	CL-ML	20.7	1.58	
7	119-143	34.0	15.0	CL	22.5	1.54	1.5×10^{-7}
7	324-374	28.0	15.0	CL			
7	654-705	29.0	13.0	CL			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classification	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
7	984-1035	33.0	18.0	CL			
7	1314-1365	31.0	17.0	CL			
7	1574-1625	NP	NP	SP-SM		1.57	1.1×10^{-3}
7	1665-1669	NP	NP	SP			
8	29-75	NP	NP	SP			
8	129-175	NP	NP	SP			
8	229-275	NP	NP	SP	4.4	1.52	
8	329-375	NP	NP	SP			
8	429-475	NP	NP	SP		1.53	2.0×10^{-2}
8	754-800	NP	NP	SP-SM		1.61	1.5×10^{-3}
9	29-57	NP	NP	ML			
9	129-165	NP	NP	ML			
9	229-275	NP	NP	SP	3.1	1.54	
9	329-375	NP	NP	SP			
9	479-525	NP	NP	SP			
9	654-700	NP	NP	SM	27.6	1.52	1.1×10^{-3}
9	945-1007	NP	NP	SM		1.65	8.5×10^{-4}
10	24-55	20.0	16.0	SM			
10	129-150	28.0	19.0	CL			
10	329-375	47.0	14.0	CL			
10	639-685	41.0	15.0	CL	19.8	1.71	
10	949-995	27.0	17.0	CL			
10	1259-1305	NP	NP	SP-SM		1.62	5.8×10^{-4}
10	1559-1605	NP	NP	SP-SM		1.62	1.6×10^{-3}
11	24-57	NP	NP	ML			
11	129-173	NP	NP	SP-SM	8.7	1.43	
11	229-275	NP	NP	SM			
11	325-373	NP	NP	SP-SM			
11	454-496	NP	NP	SM	22.6	1.54	1.5×10^{-3}
11	749-790	NP	NP	SP-SM		1.65	3.4×10^{-3}
12	24-70	31.0	18.0	CL			
12	124-165	36.0	17.0	CL	17.8	1.67	1.0×10^{-5}
12	324-350	26.0	12.0	CL			
12	619-645	39.0	18.0	CL			
12	914-965	62.0	24.0	CH			
12	1209-1242	NP	NP	SM	11.9	1.67	6.7×10^{-4}
12	1364-1405	NP	NP	SP		1.54	1.0×10^{-2}
13	29-66	25.0	16.0	CL			
13	129-162	26.0	17.0	CL			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
13	329-370	21.0	16.0	CL-ML			
13	654-698	42.0	15.0	CL	19.4	1.73	
13	979-1012	26.0	18.0	CL			
13	1304-1350	NP	NP	SP		1.54	2.2×10^{-3}
13	1604-1650	NP	NP	SP-SM		1.69	1.0×10^{-5}
14	29-62	NP	NP	ML			
14	129-175	20.0	15.0	CL-ML			
14	329-375	NP	NP	SP-SM	15.2	1.79	
14	684-730	36.0	14.0	CL			
14	1039-1085	32.0	14.0	CL			
14	1394-1432	66.0	24.0	CH			
14	1494-1540	54.0	16.0	CH	20.5	1.56	3.3×10^{-9}
14	1590-1625	NP	NP	SP			
14	1694-1730	NP	NP	SP-SM		1.68	9.4×10^{-4}
15	30-100	39.0	16.0	CL	15.9	1.76	4.9×10^{-7}
15	134-160	34.0	15.0	CL			
15	329-373	26.0	20.0	CL-ML			
15	629-673	39.0	14.0	CL	18.8	1.75	
15	929-975	NP	NP	SM			
15	1229-1275	NP	NP	SP-SM		1.58	1.3×10^{-3}
16	24-51	NP	NP	SM			
16	124-160	29.0	19.0	CL			
16	329-375	42.0	15.0	CL			
16	524-560	27.0	15.0	CL			
16	724-760	74.0	24.0	CH			
16	924-960	69.0	23.0	CH	33.9	1.41	
16	1029-1075	44.0	14.0	CL			
16	1129-1175	NP	NP	SP-SM		1.76	1.5×10^{-2}
17	24-75	25.0	19.0	CL-ML			
17	119-140	37.0	18.0	CL			
17	324-375	36.0	15.0	CL	15.5	1.94	5.8×10^{-8}
17	613-660	34.0	18.0	CL	16.9	1.75	
17	898-942	NP	NP	SM			
17	1183-1230	NP	NP	SP-SM	16.4	1.42	8.0×10^{-3}
17	1470-1492	NP	NP	SP-SM			
18	33-75	22.0	15.0	CL	16.0	1.76	
18	133-175	33.0	16.0	CL	9.3	1.81	
18	333-369	NP	NP	SM			
18	668-695	50.0	17.0	CL	19.5	1.70	4.6×10^{-9}

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classification	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
18	1003-1045	44.0	15.0	CL			
18	1333-1354	69.0	20.0	CH			
18	1488-1530	NP	NP	SP			
18	1678-1711	NP	NP	SM			
19	33-75	29.0	15.0	CL			
19	128-155	29.0	15.0	CL			
19	328-368	35.0	14.0	CL	12.6	1.77	1.2×10^{-6}
19	678-702	33.0	15.0	CL			
19	1028-1060	27.0	16.0	CL	8.3	1.81	
19	1383-1425	32.0	15.0	CL	20.1	1.64	1.2×10^{-6}
19	1533-1575	NP	NP	SM			
19	1670-1690	NP	NP	SP			
20	33-75	27.0	18.0	CL			
20	128-145	34.0	17.0	CL			
20	333-363	NP	NP	SM			
20	668-710	41.0	13.0	CL	12.4	1.89	2.2×10^{-8}
20	998-1020	23.0	17.0	CL-ML			
20	1333-1375	54.0	25.0	CH			
20	1488-1530	45.0	20.0	CL	28.6	1.48	4.7×10^{-6}
20	1630-1670	24.0	14.0	CL			
21	33-60	38.0	16.0	CL			
21	128-160	36.0	16.0	CL			
21	324-350	26.0	18.0	CL	51.3	1.32	4.7×10^{-6}
21	633-675	37.0	13.0	CL	14.8	1.80	
21	943-985	29.0	17.0	CL			
21	1248-1290	NP	NP	SM	14.5	1.54	2.2×10^{-5}
21	1540-1590	NP	NP	SP-SM			
22	28-75	30.0	17.0	CL			
22	128-170	50.0	14.0	CL	12.0	1.59	1.5×10^{-5}
22	328-373	24.0	13.0	CL	6.3	1.89	
22	613-660	30.0	15.0	CL			
22	898-945	30.0	16.0	CL			
22	1183-1230	NP	NP	SP-SM	11.7	1.61	1.2×10^{-3}
22	1333-1380	NP	NP	SP			
22	1585-1596	NP	NP	SP			
23	28-75	33.0	20.0	CL			
23	120-131	31.0	17.0	CL			
23	328-358	24.0	17.0	CL-ML	5.8	1.86	
23	683-725	36.0	15.0	CL	16.8	1.80	

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
23	1038-1085	NP	NP	SP-SM	13.1	1.53	1.9×10^{-4}
23	1393-1440	NP	NP	SP	12.5	1.66	4.2×10^{-3}
23	1680-1700	NP	NP	SP-SM			
24	28-65	26.0	19.0	CL			
24	125-165	28.0	16.0	CL	12.9	1.65	8.2×10^{-6}
24	328-360	NP	NP	SM			
24	713-760	46.0	15.0	CL			
24	1098-1145	34.0	15.0	CL	17.5	1.81	
24	1483-1530	NP	NP	SM			
24	1770-1823	NP	NP	SP-SM	18.6	1.73	5.9×10^{-4}
25	28-75	19.0	14.0	CL-ML	17.6	1.68	7.1×10^{-5}
25	128-175	30.0	13.0	CL	12.5	1.89	
25	328-365	58.0	18.0	CH			
25	690-716	30.0	22.0	CL			
25	1068-1115	30.0	16.0	CL			
25	1428-1475	NP	NP	SM	13.9	1.58	8.3×10^{-3}
25	1730-1780	NP	NP	SP			
26	28-75	NP	NP	ML	18.4	1.32	
26	124-167	41.0	15.0	CL	17.8	1.73	1.0×10^{-6}
26	324-355	NP	NP	SM	2.9	1.54	
26	663-710	47.0	16.0	CL			
26	994-1017	NP	NP	SM			
26	1333-1380	NP	NP	SP	10.1	1.61	6.8×10^{-4}
26	1620-1658	NP	NP	SM			
27	25-75	25.0	16.0	CL			
27	128-175	24.0	16.0	CL	16.5	1.73	1.1×10^{-5}
27	324-375	34.0	13.0	CL			
27	709-760	43.0	16.0	CL			
27	1098-1145	48.0	19.0	CL	25.1	1.60	
27	1479-1530	32.0	17.0	CL			
27	1779-1819	21.0	13.0	CL	20.2	1.66	5.9×10^{-6}
28	28-57	40.0	16.0	CL			
28	128-175	17.0	15.0	SM			
28	328-375	60.0	19.0	CH	24.6	1.56	1.6×10^{-9}
28	744-795	26.0	16.0	CL	16.2	1.60	4.0×10^{-7}
28	1124-1144	65.0	22.0	CH			
28	1584-1605	40.0	24.0	CL	23.7	1.56	
29	24-61	24.0	15.0	CL	18.6	1.60	
29	128-175	31.0	15.0	CL	17.0	1.64	1.4×10^{-6}

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
29	328-348	41.0	14.0	CL			
29	818-865	38.0	16.0	CL	20.0	1.46	1.2×10^{-5}
29	1304-1322	NP	NP	SM			
30	63-85	NP	NP	SM			
30	143-184	26.0	10.0	CL			
30	400-450	NP	NP	ML			
30	713-753	51.0	14.0	CH	18.6	1.74	
30	1093-1135	27.0	20.0	CL-ML	24.1	1.57	1.9×10^{-4}
30	1465-1510	NP	NP	SP-SM		1.56	1.7×10^{-4}
30	1755-1797	NP	NP	SM			
31	20-47	61.0	22.0	CH	29.2	1.47	2.1×10^{-5}
31	108-150	NP	NP	ML	29.9	1.48	2.8×10^{-5}
31	408-450	33.00		CL	32.1	1.41	
32	33-70	24.0	17.0	CL-ML	19.7	1.59	
32	128-155	32.0	16.0	CL	17.5	1.69	2.4×10^{-8}
32	329-375	29.0	20.0	CL			
32	574-620	54.0	18.0	CH			
32	815-835	32.0	19.0	CL			
32	1060-1120	NP	NP	SP-SM	20.4	1.49	5.0×10^{-4}
32	1368-1410	NP	NP	SM			
33	25-45	38.0	15.0	CL			
33	128-175	28.0	12.0	CL	15.3	1.79	7.8×10^{-8}
33	328-375	NP	NP	SM		1.73	3.8×10^{-4}
33	628-675	NP	NP	SP-SM			
34	28-65	31.0	13.0	CL			
34	128-175	34.0	14.0	CL			
34	328-375	NP	NP	SM			
34	525-558	47.0	16.0	CL	19.9	1.70	9.7×10^{-8}
34	718-762	47.0	16.0	CL			
34	913-944	58.0	26.0	CH			
34	1013-1060	34.0	14.0	CL			
34	1113-1160	NP	NP	SP-SM		1.73	3.5×10^{-6}
34	1200-1226	NP	NP	SP-SM	17.2	1.69	
35	23-76	24.0	18.0	CL-ML			
35	123-160	38.0	16.0	CL			
35	328-375	39.0	14.0	CL	16.4	1.73	2.3×10^{-8}
35	553-593	53.0	16.0	CH			
35	783-822	50.0	22.0	CH			
35	1013-1065	NP	NP	ML	18.2	1.62	4.1×10^{-5}
35	1310-1344	NP	NP	SP			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classification	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
36	28-65	25.0	18.0	CL-ML			
36	134-149	30.0	19.0	CL			
36	335-350	26.0	16.0	CL			
36	563-590	42.0	13.0	CL	9.1	1.89	9.1×10^{-9}
36	798-825	53.0	20.0	CH			
36	1030-1050	NP	NP	SM			
36	1133-1180	24.0	21.0	ML			
36	1330-1358	NP	NP	SP		1.56	9.4×10^{-3}
37	28-93	33.0	15.0	CL			
37	128-163	33.0	14.0	CL			
37	328-370	28.0	13.0	CL			
37	568-615	23.0	16.0	CL-ML			
37	808-840	65.0	25.0	CH	17.2	1.68	8.8×10^{-10}
37	1048-1090	NP	NP	SP-SM		1.59	4.6×10^{-4}
37	1340-1385	NP	NP	SP			
38	28-47	34.0	16.0	CL			
38	128-164	33.0	15.0	CL			
38	323-353	27.0	16.0	CL			
38	528-575	45.0	16.0	CL	17.0	1.79	1.5×10^{-8}
38	723-775	NP	NP	ML	15.1	1.66	
38	923-975	NP	NP	SP-SM		1.40	5.0×10^{-5}
38	1220-1265	NP	NP	SM			
39	28-86	29.0	17.0	CL	15.2	1.71	1.2×10^{-6}
39	135-168	NP	NP	ML			
39	328-373	NP	NP	SM			
39	588-635	38.0	12.0	CL	15.2	1.81	
39	848-895	38.0	15.0	CL			
39	1108-1155	65.0	24.0	CH			
39	1258-1305	53.0	18.0	CH	13.1	1.42	
39	1478-1515	NP	NP	SP		1.71	8.8×10^{-5}
40	28-54	NP	NP	ML			
40	128-160	34.0	16.0	CL	17.0	1.70	1.6×10^{-6}
40	328-375	21.0	15.0	CL-ML			
40	628-675	52.0	15.0	CH			
40	930-945	NP	NP	ML			
40	1235-1290	NP	NP	SP-SM		1.50	4.4×10^{-4}
40	1535-1590	NP	NP	SM			
41	30-75	37.0	15.0	CL			
41	138-175	36.0	16.0	CL			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
41	328-375	NP	NP	SP			
41	573-620	47.0	15.0	CL	22.9	1.65	
41	818-865	NP	NP	SP-SM		1.67	3.6×10^{-4}
41	1055-1110	NP	NP	SP		1.54	5.6×10^{-3}
41	1355-1410	NP	NP	SP-SM			
42	20-55	25.0	17.0	CL			
42	123-180	31.0	16.0	CL			
42	328-375	35.0	13.0	CL			
42	613-648	33.0	12.0	CL			
42	898-926	50.0	16.0	CH			
42	1183-1220	83.0	21.0	CH			
42	1283-1330	67.0	26.0	CH	34.2	1.42	2.1×10^{-9}
42	1383-1415	NP	NP	SM			
42	1495-1535	27.0	13.0	CL	21.8	1.58	1.6×10^{-7}
43	0-36	24.0	16.0	CL			
43	128-160	50.0	14.0	CH			
43	328-375	53.0	30.0	MH			
43	553-600	77.0	31.0	CH			
43	765-795	NP	NP	SM			
43	1003-1050	30.0	28.0	ML	22.9	1.47	6.4×10^{-5}
43	1303-1350	50.0	27.0	CL	32.7	1.36	2.0×10^{-7}
44	23-43	38.0	15.0	CL			
44	135-197	22.0	18.0	CL-ML	21.7	1.63	7.7×10^{-7}
44	328-375	NP	NP	SM	15.7	1.87	
44	458-505	55.0	28.0	CH			
44	583-635	50.0	23.0	CL			
44	713-765	51.0	21.0	CH			
44	1018-1065	NP	NP	ML	23.5	1.46	1.7×10^{-5}
45	25-85	40.0	17.0	CL	21.8	1.58	3.5×10^{-8}
45	123-157	57.0	24.0	CH	39.9	1.26	
45	328-365	76.0	36.0	MH			
45	448-487	58.0	26.0	CH			
45	608-653	54.0	35.0	MH			
45	748-775	NP	NP	ML			
45	1043-1075	24.0	17.0	CL-ML	33.8	1.24	2.4×10^{-5}
45	1348-1395	38.0	24.0	CL			
46	28-75	30.0	16.0	CL			
46	128-175	23.0	17.0	CL-ML	12.8	1.91	1.2×10^{-5}
46	323-353	34.0	17.0	CL	15.2	1.70	

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classification	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
46	528-575	55.0	21.0	CH			
46	728-773	61.0	29.0	CH			
46	920-945	53.0	32.0	MH			
46	1228-1275	49.0	32.0	ML			
47	28-55	NP	NP	SM	34.0	1.25	1.3×10^{-4}
47	120-155	NP	NP	SM	17.0	1.69	
47	215-250	NP	NP	SP-SM			
47	528-575	60.0	28.0	CH	40.4	1.22	2.5×10^{-7}
47	823-851	36.0	22.0	CL	28.7	1.43	
48	28-75	NP	NP	SP			
48	128-175	46.0	14.0	CL			
48	328-375	37.0	16.0	CL	18.9	1.74	
48	428-460	38.0	14.0	CL			
48	528-567	70.0	23.0	CH			
48	620-685	54.0	21.0	CH	25.1	1.60	1.2×10^{-8}
48	778-825	NP	NP	SM			
48	980-1020	NP	NP	SP	15.3	1.65	4.6×10^{-3}
49	28-75	NP	NP	SP			
49	123-153	NP	NP	ML	25.6	1.43	3.2×10^{-5}
49	330-375	NP	NP	SP			
49	428-475	NP	NP	SP-SM	4.5	1.58	
49	530-575	NP	NP	SP			
49	628-675	NP	NP	SP-SM	19.3	1.49	7.3×10^{-3}
49	915-945	NP	NP	SP			
50	28-70	28.0	21.0	CL-ML			
50	128-170	29.0	20.0	CL	24.2	1.51	1.7×10^{-6}
50	228-250	NP	NP	ML			
50	328-370	NP	NP	ML	22.7	1.56	
50	428-465	NP	NP	ML			
50	728-775	NP	NP	ML	20.3	1.54	6.9×10^{-4}
51	20-75	NP	NP	SM			
51	123-175	NP	NP	ML	15.1	1.49	5.1×10^{-4}
51	323-375	NP	NP	ML			
51	438-490	NP	NP	SP			
51	553-605	NP	NP	SP			
51	665-720	NP	NP	SP	19.7	1.61	7.3×10^{-3}
51	965-1025	NP	NP	SP			
52	28-60	39.0	18.0	CL			
52	123-165	31.0	21.0	CL			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classification	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
52	328-360	57.0	23.0	CH	33.4	1.41	3.4×10^{-8}
52	433-460	NP	NP	ML			
52	543-595	40.0	17.0	CL			
52	653-705	NP	NP	ML	23.9	1.42	2.0×10^{-5}
52	953-1005	NP	NP	SM			
53	23-48	28.0	18.0	CL			
53	128-175	28.0	18.0	CL			
53	228-270	60.0	20.0	CH			
53	328-370	80.0	30.0	CH			
53	428-475	72.0	23.0	CH	41.2	1.21	1.6×10^{-8}
53	528-575	53.0	19.0	CH			
53	628-675	58.0	22.0	CH	30.5	1.45	1.1×10^{-7}
53	928-950	NP	NP	ML			
54	28-55	28.0	18.0	CL			
54	128-175	34.0	17.0	CL			
54	328-375	28.0	14.0	CL	13.2	1.86	1.6×10^{-7}
54	518-565	36.0	15.0	CL			
54	708-755	25.0	17.0	CL	16.7	1.65	4.1×10^{-6}
54	893-945	30.0	17.0	CL			
54	1198-1245	26.0	15.0	CL	23.2	1.62	
55	28-70	31.0	18.0	CL			
55	128-175	35.0	17.0	CL			
55	328-369	26.0	12.0	CL	7.9	1.84	6.0×10^{-8}
55	503-550	43.0	13.0	CL			
55	678-720	NP	NP	SM			
55	853-890	NP	NP	SP-SM	25.9	1.57	3.9×10^{-4}
55	1145-1200	29.0	14.0	CL			
56	28-75	30.0	18.0	CL			
56	115-150	32.0	17.0	CL	13.0	1.73	
56	320-359	25.0	16.0	CL	9.8	1.70	8.3×10^{-7}
56	488-535	32.0	15.0	CL			
56	649-689	43.0	14.0	CL			
56	815-880	NP	NP	SM	26.4	1.50	3.1×10^{-4}
56	1115-1170	NP	NP	SP-SM			
57	23-65	27.0	19.0	CL			
57	128-165	31.0	17.0	CL			
57	328-375	29.0	13.0	CL	15.3	1.77	9.4×10^{-7}
57	468-510	39.0	13.0	CL			
57	608-640	29.0	14.0	CL	14.3	1.88	

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
57	740-795	NP	NP	SM	12.6	1.64	2.7×10^{-4}
57	1040-1095	NP	NP	SM			
58	28-75	30.0	18.0	CL			
58	128-175	30.0	14.0	CL			
58	325-360	32.0	15.0	CL			
58	455-492	51.0	13.0	CH	16.8	1.79	3.3×10^{-9}
58	582-609	49.0	14.0	CL			
58	709-746	51.0	17.0	CH	14.5	1.88	
58	836-878	49.0	18.0	CL			
58	963-1010	NP	NP	SM	17.2	1.49	2.8×10^{-5}
59	28-75	22.0	15.0	CL-ML			
59	128-175	87.0	16.0	CH			
59	328-375	NP	NP	SM			
59	488-525	53.0	18.0	CH	22.0	1.67	
59	648-695	57.0	17.0	CH	23.6	1.59	7.5×10^{-7}
59	808-840	69.0	27.0	CH			
59	958-1000	38.0	14.0	CL			
59	1103-1145	NP	NP	SP-SM	26.6	1.57	2.2×10^{-3}
60	28-75	NP	NP	ML			
60	128-170	33.0	18.0	CL	15.5	1.81	3.3×10^{-6}
60	228-275	30.0	16.0	CL			
60	320-355	NP	NP	SM			
60	420-475	NP	NP	SM	20.6	1.77	7.7×10^{-6}
60	720-772	31.0	17.0	CL			
61	28-70	NP	NP	SP-SM			
61	128-170	24.0	16.0	CL	14.4	1.69	8.8×10^{-7}
61	328-375	21.0	13.0	CL			
61	603-645	49.0	15.0	CL	19.6	1.74	0.0
61	878-925	34.0	14.0	CL			
61	1153-1200	35.0	16.0	CL			
61	1303-1350	38.0	15.0	CL			
61	1595-1645	NP	NP	SP-SM	22.1	1.60	6.5×10^{-3}
62	20-51	30.0	17.0	CL	11.2	1.85	6.2×10^{-6}
62	228-275	34.0	15.0	CL			
62	328-375	35.0	14.0	CL			
62	468-515	51.0	21.0	CH			
62	728-775	59.0	25.0	CH			
63	28-75	26.0	17.0	CL			
63	128-170	50.0	17.0	CH			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classification	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
63	225-260	62.0	15.0	CH			
63	325-345	43.0	19.0	CL	22.3	1.58	9.0×10^{-8}
63	450-520	38.0	28.0	ML	30.9	1.42	1.0×10^{-5}
63	628-675	50.0	22.0	CL			
64	28-70	24.0	16.0	CL			
64	120-165	51.0	15.0	CH			
64	220-275	24.0	16.0	CL	24.2	1.57	2.0×10^{-7}
64	328-375	55.0	24.0	CH	42.2	1.20	2.3×10^{-8}
64	428-468	51.0	20.0	CH			
64	678-723	53.0	20.0	CH	19.1	1.60	
65	28-75	27.0	16.0	CL			
65	128-175	26.0	13.0	CL			
65	328-376	27.0	12.0	CL			
65	478-515	33.0	15.0	CL	14.8	1.60	5.2×10^{-6}
65	638-685	46.0	17.0	CL			
65	793-840	67.0	26.0	CH			
65	943-990	71.0	28.0	CH			
65	1093-1132	49.0	18.0	CL	22.5	1.38	2.8×10^{-6}
65	1238-1270	NP	NP	ML			
66	0-40	24.0	15.0	CL			
66	128-160	29.0	18.0	CL			
66	223-255	49.0	18.0	CL			
66	328-375	90.0	28.0	CH	41.9	1.18	1.3×10^{-9}
66	428-475	79.0	22.0	CH			
66	728-775	55.0	22.0	CH			
67	23-60	26.0	15.0	CL			
67	118-142	45.0	15.0	CL	17.7	1.67	1.2×10^{-7}
67	323-355	50.0	20.0	CH			
67	473-515	41.0	16.0	CL	25.9	1.57	5.2×10^{-7}
67	610-665	77.0	22.0	CH			
67	755-810	69.0	21.0	CH			
68	28-60	26.0	17.0	CL			
68	133-175	29.0	15.0	CL			
68	333-375	67.0	26.0	CH			
68	503-545	64.0	29.0	CH	30.0	1.35	
68	673-713	73.0	36.0	MH	34.7	1.31	1.2×10^{-5}
68	843-878	74.0	36.0	MH			
68	993-1018	58.0	27.0	CH	32.2	1.32	9.8×10^{-7}
68	1140-1158	52.0	29.0	MH			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
69	28-48	26.0	17.0	CL			
69	122-147	27.0	17.0	CL	14.1	1.83	
69	328-375	NP	NP	SM			
69	548-595	45.0	15.0	CL	21.0	1.70	5.5×10^{-9}
69	768-806	25.0	20.0	CL-ML			
69	988-1035	29.0	15.0	CL	27.2	1.55	1.7×10^{-8}
69	1280-1330	NP	NP	SP			
70	28-65	43.0	15.0	CL			
70	128-175	48.0	17.0	CL			
70	328-368	NP	NP	SM			
70	533-565	57.0	16.0	CH	20.4	1.73	0.0
70	738-780	28.0	13.0	CL			
70	935-974	NP	NP	SP-SM		1.55	3.0×10^{-5}
70	1235-1285	NP	NP	SP-SM			
71	28-65	36.0	15.0	CL			
71	120-138	NP	NP	SM			
71	328-375	NP	NP	SM			
71 (4)	543-590	43.0	14.0	CL	22.1	1.67	6.0×10^{-10}
71 (4)	572-580	NP	NP	SP-SM			
71	758-805	54.0	17.0	CH			
71	973-1015	61.0	27.0	CH			
71	1123-1170	NP	NP	SM			
71	1273-1320	34.0	14.0	CL	23.3	1.59	1.6×10^{-9}
71	1411-1448	NP	NP	SP-SM			
72	28-75	30.0	14.0	CL			
72	122-145	35.0	13.0	CL			
72	328-367	20.0	18.0	ML	14.6	1.62	
72	563-610	39.0	13.0	CL	17.5	1.78	1.2×10^{-8}
72	798-845	24.0	13.0	CL			
72	1033-1080	NP	NP	SM	11.2	1.59	4.6×10^{-4}
72	1320-1363	NP	NP	SP			
73	28-75	29.0	15.0	CL	9.6	1.71	
73	123-143	41.0	18.0	CL			
73	364-410	NP	NP	SM			
73	623-675	50.0	16.0	CH	26.3	1.56	3.9×10^{-9}
73	923-975	NP	NP	SM			
73	1225-1275	32.0	18.0	CL	29.5	1.50	4.5×10^{-7}
73	1520-1570	NP	NP	SM			
74	20-45	21.0	15.0	CL-ML			
74	125-160	87.0	34.0	CH			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classification	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
74	328-360	36.0	14.0	CL			
74	658-705	26.0	17.0	CL	15.6	1.84	1.3×10^{-5}
74	988-1030	58.0	23.0	CH			
74	1318-1365	62.0	21.0	CH			
74	1468-1515	53.0	24.0	CH	31.5	1.46	7.0×10^{-8}
74	1618-1665	28.0	19.0	CL			
74	1918-1965	68.0	26.0	CH	28.1	1.44	
75	28-75	29.0	17.0	CL			
75	128-165	27.0	18.0	CL	10.6	1.75	
75	328-375	18.0	16.0	ML	13.9	1.71	7.6×10^{-5}
75	679-725	41.0	20.0	CL			
75	1028-1075	62.0	29.0	CH	36.1	1.29	9.0×10^{-7}
75	1378-1425	58.0	22.0	CH			
76	28-75	18.0	13.0	CL-ML			
76	128-175	40.0	14.0	CL			
76	328-375	18.0	17.0	ML			
76	628-675	58.0	19.0	CH	35.3	1.37	1.7×10^{-8}
76	928-975	43.0	24.0	CL	32.0	1.42	
76	1228-1275	72.0	33.0	CH	37.4	1.29	8.1×10^{-8}
77	28-75	28.0	17.0	CL			
77	128-175	31.0	14.0	CL			
77	328-368	63.0	22.0	CH	29.9	1.45	
77	528-575	72.0	28.0	CH	30.5	1.36	
77	728-775	50.0	21.0	CH	40.3	1.21	2.6×10^{-5}
77	928-975	66.0	30.0	CH	32.0	1.34	7.3×10^{-7}
78	28-75	35.0	15.0	CL			
78	128-175	59.0	19.0	CH			
78	328-365	47.0	21.0	CL	20.5	1.61	2.6×10^{-7}
78	528-575	33.0	18.0	CL			
78	728-775	57.0	25.0	CH	33.9	1.39	5.8×10^{-7}
78	928-975	43.0	22.0	CL			
78	1128-1170	57.0	21.0	CH			
78	1328-1375	67.0	30.0	CH			
79	19-61	14.0	13.0	ML	6.1	1.54	1.6×10^{-4}
79	133-175	NP	NP	SM			
79	233-275	NP	NP	SM			
79	333-375	NP	NP	ML			
79	433-475	NP	NP	ML	23.2	1.37	3.1×10^{-4}
79	725-760	NP	NP	SP-SM			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
80	28-75	36.0	15.0	CL			
80	128-175	31.0	16.0	CL	14.5	1.76	1.3×10^{-5}
80	228-275	30.0	21.0	CL	22.8	1.60	3.4×10^{-6}
80	328-375	39.0	23.0	CL			
80	428-475	39.0	19.0	CL			
80	578-625	36.0	23.0	CL			
81	28-75	41.0	20.0	CL			
81	128-160	30.0	19.0	CL			
81	320-345	29.0	16.0	CL	14.5	1.78	
81	503-550	56.0	21.0	CH	38.5	1.29	4.8×10^{-7}
81	678-725	46.0	23.0	CL	39.5	1.25	2.7×10^{-7}
81	853-887	45.0	28.0	ML	32.6	1.32	
82	20-60	26.0	19.0	CL-ML			
82	128-175	68.0	29.0	CH	24.0	1.41	
82	228-260	47.0	20.0	CL	22.2	1.53	
82	328-375	49.0	19.0	CL	32.8	1.34	1.7×10^{-6}
82	628-675	64.0	30.0	CH	39.2	1.26	10.0×10^{-6}
83	28-75	22.0	18.0	CL-ML			
83	128-175	26.0	16.0	CL			
83	328-375	57.0	22.0	CH			
83	468-515	72.0	25.0	CH	35.7	1.34	6.2×10^{-5}
83	608-655	44.0	18.0	CL	33.2	1.35	3.0×10^{-6}
83	748-795	57.0	28.0	CH	30.2	1.36	
83	1040-1110	55.0	21.0	CH			
84	20-45	NP	NP	ML			
84	128-155	21.0	15.0	CL-ML			
84	328-375	42.0	16.0	CL	22.3	1.48	
84	518-565	NP	NP	SM	25.8	1.48	1.7×10^{-4}
84	810-830	NP	NP	SP			
85	28-75	49.0	19.0	CL			
85	128-170	33.0	20.0	CL	12.0	1.73	
85	328-375	26.0	21.0	CL-ML	17.5	1.65	
85	478-515	NP	NP	SM		1.45	5.9×10^{-4}
85	795-865	43.0	18.0	CL	26.1	1.54	7.8×10^{-7}
86	28-75	28.0	14.0	CL	14.7	1.69	
86	128-175	36.0	13.0	CL	19.0	1.75	
86	428-470	36.0	14.0	CL	16.6	1.66	9.5×10^{-5}
86	728-775	77.0	30.0	CH	43.7	1.20	1.4×10^{-7}
87	15-75	32.0	15.0	CL	13.8	1.59	1.4×10^{-4}
87	128-153	59.0	26.0	CH	25.3	1.43	

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
87	328-356	69.0	31.0	CH	44.1	1.22	
87	428-470	58.0	29.0	CH	38.1	1.30	9.7×10^{-7}
87	528-560	52.0	22.0	CH	32.3	1.40	
87	728-760	NP	NP	ML	35.6	1.32	
88	28-75	31.0	13.0	CL			
88	128-175	43.0	15.0	CL			
88	360-375	56.0	20.0	CH	24.2	1.42	1.2×10^{-6}
88	425-465	48.0	32.0	ML	19.1	1.60	
88	525-550	61.0	32.0	MH			
88	828-875	56.0	39.0	MH	41.0	1.23	3.0×10^{-5}
89	28-75	NP	NP	ML			
89	160-175	32.0	16.0	CL	17.0	1.67	3.5×10^{-5}
89	328-375	54.0	21.0	CH			
89	428-469	54.0	29.0	CH			
89	628-654	48.0	21.0	CL	28.7	1.46	7.0×10^{-7}
90	28-75	27.0	16.0	CL			
90	120-150	43.0	15.0	CL	16.3	1.61	7.5×10^{-8}
90	328-375	49.0	31.0	CL			
90	460-475	40.0	29.0	ML	29.3	1.40	4.3×10^{-7}
91	28-75	23.0	19.0	CL-ML			
91	128-175	28.0	17.0	CL	17.1	1.48	1.4×10^{-6}
91	335-360	NP	NP	SM	15.9	1.61	6.9×10^{-10}
91	420-442	NP	NP	SM			
91	528-575	51.0	17.0	CH	22.5	1.50	0.3×10^{-6}
91	828-875	42.0	20.0	CL	26.5	1.54	0.4×10^{-6}
92	28-75	19.0	17.0	ML			
92	128-160	24.0	17.0	CL			
92	225-247	30.0	20.0	CL			
92	358-405	35.0	26.0	ML	26.3	1.50	3.3×10^{-6}
92	628-675	50.0	25.0	CH	31.1	1.43	2.5×10^{-6}
93	20-75	25.0	16.0	CL			
93	128-175	48.0	19.0	CL	11.0	1.76	8.0×10^{-7}
93	328-375	27.0	15.0	CL			
93	430-465	21.0	15.0	CL-ML			
93	578-620	NP	NP	SM	13.0	1.73	3.6×10^{-5}
93	878-925	NP	NP	ML			
94	28-60	39.0	17.0	SC			
94	128-175	64.0	31.0	CH	33.8	1.36	2.9×10^{-6}
94	228-275	73.0	31.0	CH			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classification	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
94	328-375	73.0	29.0	CH	37.6	1.28	2.1×10^{-6}
94	628-667	77.0	28.0	CH			
95	28-75	NP	NP	SC			
95	120-127	35.0	29.0	ML			
95	228-275	67.0	32.0	CH	41.9	1.24	
95	328-375	51.0	28.0	CH	36.9	1.34	2.1×10^{-8}
95	630-650	36.0	34.0	ML			
96	28-75	NP	NP	SM			
96	128-175	NP	NP	SM	18.0	1.75	3.5×10^{-5}
96	225-275	NP	NP	SM			
96	528-575	64.0	23.0	CH	37.0	1.32	
97	28-75	37.0	15.0	CL			
97	128-175	33.0	17.0	CL			
97	228-275	27.0	20.0	CL			
97	328-355	55.0	19.0	CH			
97	428-475	51.0	19.0	CH	22.8	1.55	1.5×10^{-9}
97	578-525	24.0	13.0	CL			
97	678-703	NP	NP	SM			
97	778-813	NP	NP	ML	25.4	1.61	2.9×10^{-6}
97	1065-1090	NP	NP	SP			
98	28-75	22.0	15.0	CL			
98	128-175	32.0	15.0	CL	21.6	1.62	8.3×10^{-7}
98	228-275	27.0	17.0	CL			
98	323-358	26.0	18.0	SC			
98	578-625	36.0	18.0	CL	11.8	1.64	2.17×10^{-5}
99	28-75	21.0	17.0	CL-ML			
99	128-175	25.0	15.0	CL			
99	228-275	29.0	16.0	CL			
99	328-370	30.0	14.0	SC			
99	428-470	NP	NP	SP-SM	8.2	1.61	2.87×10^{-5}
99	528-575	NP	NP	SM			
99	628-675	NP	NP	SM			
99	920-952	NP	NP	SM			
100	20-66	38.0	15.0	CL	20.0	1.57	3.93×10^{-6}
100	120-145	74.0	23.0	CH			
100	225-263	87.0	28.0	CH			
100	310-335	NP	NP	ML			
100	433-475	27.0	14.0	CL			
100	528-575	24.0	18.0	SC-SM	20.5	1.72	1.48×10^{-5}
100	813-838	NP	NP	SP-SM			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
101	28-75	33.0	17.0	CL			
101	118-172	NP	NP	ML			
101	228-275	NP	NP	ML			
101	328-375	27.0	22.0	CL-ML	6.4	1.45	1.21×10^{-4}
101	470-495	NP	NP	SM			
101	620-675	24.0	22.0	ML	21.6	1.65	1.00×10^{-5}
101	915-940	NP	NP	SP			
102	28-75	37.0	18.0	CL	4.5	1.53	1.13×10^{-4}
102	110-140	44.0	20.0	CL			
102	323-375	NP	NP	SM	30.5	1.49	1.22×10^{-5}
102	420-440	NP	NP	ML			
102	715-755	NP	NP	SM			
103	28-60	NP	NP	ML			
103	128-175	48.0	19.0	CL			
103	228-260	38.0	18.0	CL	11.0	1.51	1.13×10^{-4}
103	330-360	24.0	25.0	ML	19.5	1.51	5.31×10^{-5}
103	620-675	NP	NP	SP			
104	28-75	NP	NP	ML			
104	128-158	51.0	19.0	CH			
104	228-258	NP	NP	ML	18.7	1.52	4.12×10^{-4}
104	328-375	NP	NP	SM	23.4	1.62	4.75×10^{-4}
104	620-650	21.0	16.0	CL-ML			
105	28-75	18.0	17.0	ML			
105	128-175	NP	NP	SM			
105	228-275	27.0	16.0	SC		1.65	5.44×10^{-7}
105	328-375	28.0	20.0	SC			
105	428-475	NP	NP	SP-SM		1.51	6.34×10^{-5}
105	748-795	NP	NP	SP-SM			
106	28-63	24.0	14.0	SC			
106	123-160	27.0	16.0	SC			
106	325-355	30.0	22.0	CL			
106	475-510	NP	NP	SM			
106	628-660	34.0	26.0	ML			
106	725-750	37.0	23.0	CL			
106	1028-1075	NP	NP	SM		1.47	5.66×10^{-4}
107	23-55	17.0	17.0	ML			
107	128-175	23.0	17.0	CL-ML		1.72	2.26×10^{-4}
107	328-375	26.0	24.0	SM			
107	493-540	42.0	18.0	SC		1.30	2.74×10^{-5}

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm	Atterberg Limits, Percent Water		USCS Classifi- cation	Water Content, %	Density, g/cc	Permeability, cm/sec
		Liquid Limit	Plastic Limit				
107	658-701	NP	NP	SM			
107	823-870	34.0	24.0	CL			
107	978-1025	NP	NP	SM			
107	1178-1215	NP	NP	SM			
108	0-70	20.0	17.0	ML			
108	174-198	39.0	14.0	CL			
108	329-366	23.0	14.0	CL			
108	478-500	38.0	14.0	CL			
108	628-664	24.0	14.0	CL			
108	783-811	36.0	13.0	CL			
108	930-966	27.0	16.0	CL			
108	1079-1088	NP	NP	SM			
108	1228-1253	NP	NP	SM			
108	1381-1411	NP	NP	SM			
108	1524-1539	NP	NP	SM			
108	1652-1695	NP	NP	SP			
108	1798-1844	NP	NP	SP-SM			
108	1948-1993	NP	NP	SM			
108	2100-2146	NP	NP	SM			
108	2280-2316	87.0	24.0	CH			
108	2429-2448	45.0	22.0	CL			
108	2551-2579	NP	NP	SP-SM			
108	2700-2728	47.0	20.0	CL			
108	2850-2896	NP	NP	SM			
108	3170-3191	NP	NP	SP-SM			
108	3331-3374	42.0	16.0	CL			
108	3472-3520	44.0	16.0	CL			
108	3630-3670	60.0	23.0	CH		1.48	1.68 x 10 ⁻⁶
108	3780-3816	75.0	30.0	CH			
108	3932-3968	44.0	18.0	CL			
109	30-70	26.0	18.0	CL			
109	162-174	25.0	17.0	CL			
109	344-369	NP	NP	SM			
109	631-668	48.0	15.0	CL			
109	930-948	27.0	17.0	CL			
109	1231-1268	19.0	16.0	ML		1.69	4.65 x 10 ⁻⁷
109	1500-1545	NP	NP	SM			
109	1810-1826	NP	NP	SM			
109	2100-2121	41.0	21.0	CL			

(Continued)

Table 4. Physical Test Results

Boring No.	Sample Depth, cm.	Atterberg Limits, Percent Water		USCS Classification	Water Content, %	Density, g/cc	Permeability, cm/sec.
		Liquid Limit	Plastic Limit				
109	2722-2743	50.2	24.4	CH			
109	2999-3005	36.0	26.0	ML			
109	3612-3636	43.0	36.0	ML			
109	4221-4267	71.0	30.0	CH	1.25		4.97×10^{-7}
110	21-70	44.0	19.0	CL			
110	171-198	35.0	14.0	CL	1.77		2.01×10^{-6}
110	320-366	23.0	17.0	CL-ML			
110	622-658	35.0	13.0	CL			
110	920-957	NP	NP	SM			
110	1231-1268	NP	NP	ML			
110	1521-1567	NP	NP	SM	1.70		5.89×10^{-4}
110	1829-1865	NP	NP	SM			
110	2121-2152	20.0	10.0	CL			
110	2429-2463	NP	NP	SM			
110	2880-2908	61.0	30.0	CH	1.37		6.07×10^{-7}
110	3018-3045	41.0	25.0	CL			
111	21-70	36.0	16.0	CL			
111	171-189	40.0	18.0	CL			
111	320-354	39.0	14.0	CL			
111	622-649	70.0	19.0	CH	1.48		2.12×10^{-8}
111	920-957	22.0	19.0	ML			
111	1231-1262	NP	NP	SM			
111	1521-1576	NP	NP	SM	1.51		5.93×10^{-4}
111	1820-1856	NP	NP	SP-SM			
111	2121-2167	NP	NP	ML			
111	2420-2435	NP	NP	SM			
111	2774-2822	60.0	30.0	CH			
111	3020-3060	50.0	18.0	CH			
111	3322-3347	46.0	31.0	ML			1.0339×10^{-7}
111	3609-3618	40.0	23.0	CL			
111	3923-3972	43.0	19.0	CL			
111	4221-4264	31.0	23.0	ML			
111	4831-4868	38.0	27.0	ML			
111	5124-5172	85.0	35.0	CH			481×10^{-6}

Table 5
Water Table Elevations

Boring No.	Water Table Elevation, cms	
	24 Jun - 29 Jul 1977	2 - 4 Aug 1977
1	6097	6133
2	No Piezometer	
3	6098	6090
4	6116	6108
5	6074	6027
6	6411	6366
7	6047	6118
8	6020	6012
9	6035	6018
10	6107	6102
11	6052	6045
12	6052	6055
13	6107	6100
14	6202	6118
15	6111	6105
16	*	6107
17	6116	6095
18	6104	6096
19	6121	6106
20	6120	6109
21	6113	6105
22	6044	6106
23	6034	6042
24	6051	6052
25	6041	6043
26	6035	6025
27	6075	6043
28	6954	6892
29	7017	7015
30	6131	6127
31	5928	5933
32	6098	6091
33	6080	6071
34	6085	6036
35	6112	6104
36	6064	6058
37	6170	6168
38	6142	6134
39	6636	6735
40	6145	6148
41	6139	6133
42	6224	6138

* No Data

(Continued)

Table 5
Water Table Elevations

Boring No.	Water Table Elevation, cms	
	24 Jun - 29 Jul 1977	2 - 4 Aug 1977
43	7582	7574
44	7568	7564
45	8016	8033
46	8146	8141
47	7566	7838
48	6123	6108
49	6037	6003
50	6066	6051
51	6053	6015
52	6076	6007
53	7853	7792
54	6057	6051
55	6106	6014
56	6026	6018
57	6133	6125
58	6161	6149
59	6183	6173
60	6254	6232
61	6180	6176
62	7813	7799
63	7464	7480
64	7310	7312
65	6913	7014
66	8021	8018
67	8288	8282
68	8435	8433
69	6185	6183
70	6115	6112
71	*	6117
72	6112	6109
73	6181	6179
74	6643	6731
75	7156	7152
76	7276	7273
77	7445	7443
78	8038	7935
79	6057	6068
80	7484	7490
81	7394	7408
82	7987	7986

* No Data

(Continued)

Table 5
Water Table Elevations

Boring No.	Water Table Elevation, cms	
	24 Jun - 29 Jul 1977	2 - 4 Aug 1977
83	8308	8308
84	9095	9105
85	8886	9223
86	9029	9623
87	9524	9519
88	9031	9030
89	8072	8065
90	8764	8747
91	9062	9062
92	7976	7978
93	7598	7596
94	7116	7108
95	7415	7514
96	6389	6389
97	6086	6082
98	6297	6298
99	*	6093
100	6035	6036
101	6029	5787
102	5995	5979
103	5992	5981
104	5984	5972
105	7621	7620
106	7639	7637
107	7636	7635

* No Data

REFERENCES

- Broughton, Jerald D. 1977. "A Literature Survey on Surface and Subsurface Characteristics at Pine Bluff Arsenal, Arkansas - Draft," U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, 42 pp.
- Caplan, W. M. 1954. "Subsurface Geology and Related Oil and Gas Possibilities of Northeastern Arkansas," Bulletin 20, Arkansas Resources Development Commission, Little Rock.
- Cooke, C. Wythe. 1966. "Emerged Quaternary Shore Lines in the Mississippi Embayment," Vol. 149, No. 10, Publication 4677, Smithsonian Institution, Washington, DC, 41 pp.
- Cushing, E. M., Boswell, E. H., and Hosman, R. L. 1964. "General Geology of the Mississippi Embayment," Professional Paper 448-B, U. S. Geological Survey, Washington, DC, 28 pp.
- Dunbar, C. O. and Waage, K. M. 1969. Historical Geology, John Wiley and Sons, Inc., New York.
- Lachapelle, David G.; Brooks, Alan E.; and Trescott, Edward B. 1969. "Groundwater Monitoring, Pine Bluff Arsenal, Arkansas," Technical Report 4287, Edgewood Arsenal, Maryland.
- Pinkham, Carlos F. A., et al. 1975. "Preliminary Environmental Survey, Pine Bluff Arsenal, Pine Bluff, Arkansas, December 1972," EB-SP-74025, Edgewood Arsenal, Aberdeen Proving Ground, MD.
- U. S. Army Chemical Systems Laboratory. 1977. "IR Data Management User's Guide," Aberdeen Proving Ground, MD.
- U. S. Army Chemical Systems Laboratory. 1979. "Records Research, Pine Bluff Arsenal, Arkansas," Aberdeen Proving Ground, Maryland.
- U. S. Army Environmental Hygiene Agency. 1970. "Sanitary Engineering Survey No. 24-033-70, Pine Bluff Arsenal, Pine Bluff, Arkansas, 2-6 March 1979," Edgewood Arsenal, Maryland.
- U. S. Army Environmental Hygiene Agency. 1972. "Water Quality Engineering Survey No. 24-002-73, Pine Bluff Arsenal, Pine Bluff, Arkansas, 17-21 July 1970," Edgewood Arsenal, Maryland.
- U. S. Army Environmental Hygiene Agency. 1974. "Water Quality Geohydrologic Consultation No. 24-004-74, Pine Bluff Arsenal, Pine Bluff, Arkansas, 16-20 July 1973," Aberdeen Proving Ground, Maryland.

U. S. Army Environmental Hygiene Agency. 1976. "DDT Containment, Pine Bluff Arsenal, Pine Bluff, Arkansas, 28-31 July 1975," Installation Restoration Program Report No. 99-065-75/76, Aberdeen Proving Ground, Maryland.

U. S. Army Map Service. 1955. "Little Rock, Arkansas," Topographic Map, Color, 1:250,000, Washington, DC.

U. S. Department of the Army. 1970. "Engineering and Design, Laboratory Soil Testing," EM 1110-2-1906, Washington, D. C.

U. S. Department of the Army, 1972. "Engineering and Design, Soil Sampling," EM 1110-2-1907, Washington, DC.

VTN. 1975. "Environmental Inventory and Analysis for Pine Bluff, Arkansas," 2 vols, Metairie, Louisiana.

APPENDIX A
WELL INSTALLATION AND WATER LEVEL DATA

One hundred and six of the PBA borings were developed as groundwater monitoring wells. The data applicable to each well and the groundwater measurements made during the study are presented in the following tabulation. Keys to the computer-retrieved data are:

ENTRY	EXPLANATION
BOREHOLE NO	Boring Number
FD INT MEAS	Field Drilling File, <u>Interval Measured</u>
FD INT VALUE CM	Field Drilling File, <u>Interval Value</u> , centimeters
WE001	Waterways Experiment Station Boring 001
STKUP	Stick Up, PVC pipe above ground level
67.00	Measured Value
FD INT DEPTH CM	Field Drilling File, <u>Interval Depth</u> , centimeters
FD INT THICK CM	Field Drilling File, <u>Interval Thickness</u> , centimeters
SFILT	Sand Filter, sand emplaced around well screen
SCREN	Screen, slotted PVC pipe
GROUT	Grout, water-cement-bentonite mixture placed from the top of the sand filter to the ground surface
WELL NO	Groundwater monitoring well number
GW STAB DEPTH CM	Groundwater Stabilized Depth, centimeters
GW STAB DATE	Groundwater Stabilized Date; day the measurement was made
08/03/1977	Date (month, day, year)

BORE HOLE NO	FD INT MEAS	FD INT VALUE CM
WE001	STKUP	67.00
WE003	STKUP	30.00
WE004	STKUP	30.00
WE005	STKUP	100.00
WE006	STKUP	100.00
WE007	STKUP	100.00
WE008	STKUP	150.00
WE009	STKUP	100.00
WE010	STKUP	90.00
WE011	STKUP	155.00
WE012	STKUP	150.00
WE013	STKUP	100.00
WE014	STKUP	100.00
WE015	STKUP	100.00
WE016	STKUP	100.00
WE017	STKUP	100.00
WE018	STKUP	91.00
WE019	STKUP	95.00
WE020	STKUP	100.00
WE021	STKUP	100.00
WE022	STKUP	100.00
WE023	STKUP	105.00
WE024	STKUP	100.00
WE025	STKUP	100.00
WE026	STKUP	100.00
WE027	STKUP	100.00
WE028	STKUP	100.00
WE029	STKUP	100.00
WE030	STKUP	100.00
WE031	STKUP	100.00
WE032	STKUP	100.00
WE033	STKUP	100.00
WE034	STKUP	100.00
WE035	STKUP	100.00
WE036	STKUP	100.00
WE037	STKUP	100.00
WE038	STKUP	100.00
WE039	STKUP	100.00
WE040	STKUP	100.00
WE041	STKUP	100.00
WE042	STKUP	100.00
WE043	STKUP	100.00
WE044	STKUP	100.00
WE045	STKUP	100.00
WE046	STKUP	100.00
WE047	STKUP	100.00
WE048	STKUP	100.00
WE049	STKUP	100.00
WE050	STKUP	100.00
WE051	STKUP	100.00
WE052	STKUP	100.00
WE053	STKUP	100.00
WE054	STKUP	100.00

<u>BORE HOLE NO</u>	<u>FD INT MEAS</u>	<u>FD INT VALUE CM</u>
WE055	STKUP	100.00
WE056	STKUP	100.00
WE057	STKUP	100.00
WE058	STKUP	100.00
WE059	STKUP	100.00
WE060	STKUP	100.00
WE061	STKUP	100.00
WE062	STKUP	100.00
WE063	STKUP	85.00
WE064	STKUP	100.00
WE065	STKUP	100.00
WE066	STKUP	100.00
WE067	STKUP	100.00
WE068	STKUP	100.00
WE069	STKUP	100.00
WE070	STKUP	100.00
WE071	STKUP	100.00
WE072	STKUP	82.00
WE073	STKUP	100.00
WE074	STKUP	100.00
WE075	STKUP	100.00
WE076	STKUP	100.00
WE077	STKUP	100.00
WE078	STKUP	100.00
WE079	STKUP	100.00
WE080	STKUP	100.00
WE081	STKUP	100.00
WE082	STKUP	100.00
WE083	STKUP	100.00
WE084	STKUP	100.00
WE085	STKUP	100.00
WE086	STKUP	100.00
WE087	STKUP	100.00
WE088	STKUP	100.00
WE089	STKUP	100.00
WE090	STKUP	100.00
WE091	STKUP	100.00
WE092	STKUP	100.00
WE093	STKUP	100.00
WE094	STKUP	100.00
WE095	STKUP	100.00
WE096	STKUP	150.00
WE097	STKUP	100.00
WE098	STKUP	100.00
WE099	STKUP	100.00
WE100	STKUP	100.00
WE101	STKUP	100.00
WE102	STKUP	100.00
WE103	STKUP	100.00
WE104	STKUP	150.00
WE105	STKUP	100.00
WE106	STKUP	100.00
WE107	STKUP	100.00

BORE HOLE NO	FD INT MEAS.	FD INT DEPTH CM	FD INT THICK CM
WE001	SFILT	1006	299
WE003	SFILT	1160	1390
WE004	SFILT	1065	800
WE005	SFILT	40	460
WE006	SFILT	150	405
WE007	SFILT	900	825
WE008	SFILT	300	500
WE009	SFILT	475	532
WE010	SFILT	1050	555
WE011	SFILT	250	634
WE012	SFILT	1050	586
WE013	SFILT	1125	645
WE014	SFILT	915	915
WE015	SFILT	1050	596
WE016	SFILT	800	520
WE017	SFILT	1000	635
WE018	SFILT	1050	748
WE019	SFILT	1200	590
WE020	SFILT	1150	530
WE021	SFILT	1050	550
WE022	SFILT	1100	612
WE023	SFILT	1200	476
WE024	SFILT	1300	628
WE025	SFILT	1250	435
WE026	SFILT	1150	628
WE027	SFILT	850	969
WE028	SFILT	900	707
WE029	SFILT	825	497
WE030	SFILT	914	1012
WE031	SFILT	100	366
WE032	SFILT	610	863
WE033	SFILT	200	475
WE034	SFILT	725	584
WE035	SFILT	840	600
WE036	SFILT	975	505
WE037	SFILT	609	1077
WE038	SFILT	675	635
WE039	SFILT	950	592
WE040	SFILT	1050	718
WE041	SFILT	850	560
WE042	SFILT	950	600
WE043	SFILT	775	575
WE044	SFILT	600	465
WE045	SFILT	450	950
WE046	SFILT	750	525
WE047	SFILT	150	392
WE048	SFILT	550	605
WE049	SFILT	525	481
WE050	SFILT	300	475
WE051	SFILT	550	415
WE052	SFILT	425	580
WE053	SFILT	450	520
WE054	SFILT	750	495

<u>BORE HOLE NO</u>	<u>FD INT MEAS</u>	<u>FD INT DEPTH CM</u>	<u>FD INT THICK CM</u>
WE055	SFILT	700	500
WE056	SFILT	625	545
WE057	SFILT	625	470
WE058	SFILT	600	428
WE059	SFILT	650	505
WE060	SFILT	200	572
WE061	SFILT	1100	550
WE062	SFILT	150	655
WE063	SFILT	175	500
WE064	SFILT	300	423
WE065	SFILT	650	620
WE066	SFILT	300	475
WE067	SFILT	325	485
WE068	SFILT	300	858
WE069	SFILT	875	455
WE070	SFILT	825	540
WE071	SFILT	875	573
WE072	SFILT	925	550
WE073	SFILT	1100	520
WE074	SFILT	1250	715
WE075	SFILT	1000	425
WE076	SFILT	400	875
WE077	SFILT	550	425
WE078	SFILT	900	475
WE079	SFILT	250	525
WE080	SFILT	250	405
WE081	SFILT	425	475
WE082	SFILT	200	475
WE083	SFILT	550	565
WE084	SFILT	215	615
WE084	SFILT	150	65
WE085	SFILT	350	520
WE086	SFILT	200	575
WE087	SFILT	300	475
WE088	SFILT	500	375
WE089	SFILT	250	404
WE090	SFILT	275	434
WE091	SFILT	350	525
WE092	SFILT	250	425
WE093	SFILT	475	450
WE094	SFILT	250	425
WE095	SFILT	275	381
WE096	SFILT	150	425
WE097	SFILT	600	550
WE098	SFILT	225	395
WE099	SFILT	400	552
WE100	SFILT	450	388
WE101	SFILT	350	590
WE102	SFILT	300	455
WE103	SFILT	300	400
WE104	SFILT	225	450
WE105	SFILT	325	470
WE106	SFILT	600	475
WE107	SFILT	700	515

BORE HOLE NO	FD INT MEAS	FD INT DEPTH CM	FD INT THICK CM
WE001	SCREEN	1155	137
WE003	SCREEN	1350	125
WE004	SCREEN	1280	130
WE005	SCREEN	60	195
WE006	SCREEN	280	135
WE007	SCREEN	1350	130
WE008	SCREEN	424	130
WE009	SCREEN	625	137
WE010	SCREEN	1250	130
WE011	SCREEN	405	130
WE012	SCREEN	1210	135
WE013	SCREEN	1275	135
WE014	SCREEN	1365	130
WE015	SCREEN	1200	130
WE016	SCREEN	900	130
WE017	SCREEN	1155	135
WE018	SCREEN	1325	135
WE019	SCREEN	1350	140
WE020	SCREEN	1305	125
WE021	SCREEN	1200	135
WE022	SCREEN	1250	130
WE023	SCREEN	1345	135
WE024	SCREEN	1460	130
WE025	SCREEN	1400	135
WE026	SCREEN	1300	130
WE027	SCREEN	1300	130
WE028	SCREEN	1040	130
WE029	SCREEN	975	135
WE030	SCREEN	1440	130
WE031	SCREEN	150	125
WE032	SCREEN	1050	125
WE033	SCREEN	350	125
WE034	SCREEN	875	135
WE035	SCREEN	990	130
WE036	SCREEN	1025	125
WE037	SCREEN	1025	140
WE038	SCREEN	825	125
WE039	SCREEN	1150	130
WE040	SCREEN	1200	130
WE041	SCREEN	1000	125
WE042	SCREEN	1175	135
WE043	SCREEN	925	135
WE044	SCREEN	700	125
WE045	SCREEN	500	135
WE046	SCREEN	600	135
WE047	SCREEN	200	130
WE048	SCREEN	650	135
WE049	SCREEN	625	125
WE050	SCREEN	400	130
WE051	SCREEN	650	130
WE052	SCREEN	575	135
WE053	SCREEN	550	135

<u>BORE HOLE NO</u>	<u>FD INT MEAS</u>	<u>FD INT DEPTH CM</u>	<u>FD INT THICK CM</u>
WE054	SCREEN	850	130
WE055	SCREEN	900	135
WE056	SCREEN	725	130
WE057	SCREEN	725	130
WE058	SCREEN	700	130
WE059	SCREEN	750	130
WE060	SCREEN	300	135
WE061	SCREEN	1200	135
WE062	SCREEN	200	130
WE063	SCREEN	225	130
WE064	SCREEN	350	130
WE065	SCREEN	750	135
WE066	SCREEN	375	140
WE067	SCREEN	425	130
WE068	SCREEN	400	135
WE069	SCREEN	975	135
WE070	SCREEN	925	140
WE071	SCREEN	975	130
WE072	SCREEN	996	135
WE073	SCREEN	1200	135
WE074	SCREEN	1350	130
WE075	SCREEN	1100	125
WE076	SCREEN	500	135
WE077	SCREEN	650	135
WE078	SCREEN	1000	135
WE079	SCREEN	350	135
WE080	SCREEN	350	135
WE081	SCREEN	525	135
WE082	SCREEN	275	130
WE083	SCREEN	650	130
WE084	SCREEN	200	130
WE085	SCREEN	450	135
WE086	SCREEN	275	140
WE087	SCREEN	400	140
WE088	SCREEN	550	130
WE089	SCREEN	300	145
WE090	SCREEN	350	135
WE091	SCREEN	475	140
WE092	SCREEN	300	135
WE093	SCREEN	575	130
WE094	SCREEN	300	140
WE095	SCREEN	325	130
WE096	SCREEN	200	130
WE097	SCREEN	750	135
WE098	SCREEN	275	135
WE099	SCREEN	550	140
WE100	SCREEN	450	135
WE101	SCREEN	450	130
WE102	SCREEN	350	135
WE103	SCREEN	375	130
WE104	SCREEN	275	135
WE105	SCREEN	425	140
WE106	SCREEN	700	130
WE107	SCREEN	800	135

BORE HOLE NO	FD INT MEAS	FD INT DEPTH CM	FD INT THICK CM
WE001	GROUT	0	1006
WE003	GROUT	0	1160
WE004	GROUT	0	1065
WE005	GROUT	0	40
WE006	GROUT	0	150
WE007	GROUT	0	900
WE008	GROUT	0	300
WE009	GROUT	0	475
WE010	GROUT	0	1050
WE011	GROUT	0	250
WE012	GROUT	0	1050
WE013	GROUT	0	1125
WE014	GROUT	0	915
WE015	GROUT	0	1050
WE016	GROUT	0	800
WE017	GROUT	0	1000
WE018	GROUT	0	1050
WE019	GROUT	0	1200
WE020	GROUT	0	1150
WE021	GROUT	0	1050
WE022	GROUT	0	1100
WE023	GROUT	0	1200
WE024	GROUT	0	1300
WE025	GROUT	0	1250
WE026	GROUT	0	1150
WE027	GROUT	0	650
WE028	GROUT	0	900
WE029	GROUT	0	825
WE030	GROUT	0	914
WE031	GROUT	0	100
WE032	GROUT	0	610
WE033	GROUT	0	200
WE034	GROUT	0	725
WE035	GROUT	0	840
WE036	GROUT	0	975
WE037	GROUT	0	609
WE038	GROUT	0	675
WE039	GROUT	0	950
WE040	GROUT	0	1050
WE041	GROUT	0	850
WE042	GROUT	0	950
WE043	GROUT	0	775
WE044	GROUT	0	600
WE045	GROUT	0	450
WE046	GROUT	0	750
WE047	GROUT	0	150
WE048	GROUT	0	550
WE049	GROUT	0	525
WE050	GROUT	0	300
WE051	GROUT	0	550
WE052	GROUT	0	425
WE053	GROUT	0	450
WE054	GROUT	0	750

<u>BORE HOLE NO</u>	<u>FD INT MEAS</u>	<u>FD INT DEPTH CM</u>	<u>FD INT THICK CM</u>
* WE055	GROUT	0	700
* WE056	GROUT	0	625
* WE057	GROUT	0	625
* WE058	GROUT	0	600
* WE059	GROUT	0	650
* WE060	GROUT	0	200
* WE061	GROUT	0	1100
* WE062	GROUT	0	150
* WE063	GROUT	0	175
* WE064	GROUT	0	300
* WE065	GROUT	0	650
* WE066	GROUT	0	300
* WE067	GROUT	0	325
* WE068	GROUT	0	300
* WE069	GROUT	0	875
* WE070	GROUT	0	825
* WE071	GROUT	0	875
* WE072	GROUT	0	925
* WE073	GROUT	0	1100
* WE074	GROUT	0	1250
* WE075	GROUT	0	1000
* WE076	GROUT	0	400
* WE077	GROUT	0	550
* WE078	GROUT	0	900
* WE079	GROUT	0	250
* WE080	GROUT	0	250
* WE081	GROUT	0	425
* WE082	GROUT	0	200
* WE083	GROUT	0	550
* WE084	GROUT	0	150
* WE085	GROUT	0	350
* WE086	GROUT	0	200
* WE087	GROUT	0	300
* WE088	GROUT	0	500
* WE089	GROUT	0	250
* WE090	GROUT	0	275
* WE091	GROUT	0	350
* WE092	GROUT	0	250
* WE093	GROUT	0	475
* WE094	GROUT	0	250
* WE095	GROUT	0	275
* WE096	GROUT	0	150
* WE097	GROUT	0	600
* WE098	GROUT	0	225
* WE099	GROUT	0	400
* WE100	GROUT	0	450
* WE101	GROUT	0	350
* WE102	GROUT	0	300
* WE103	GROUT	0	300
* WE104	GROUT	0	225
* WE105	GROUT	0	325
* WE106	GROUT	0	600
* WE107	GROUT	0	700

WELL NO	GW STAB DEPTH CM	GW STAB DATE
WE001	1131	08/03/1977
WE003	1318	08/03/1977
WE005	1318	08/03/1977
WE004	1268	08/03/1977
WE006	77	08/03/1977
WE007	238	08/03/1977
WE008	1263	08/03/1977
WE009	428	08/03/1977
WE010	580	08/03/1977
WE011	1232	08/03/1977
WE012	393	08/03/1977
WE013	1230	08/03/1977
WE014	1264	08/02/1977
WE015	1338	08/03/1977
WE016	1184	08/02/1977
WE017	888	08/03/1977
WE018	1172	08/03/1977
WE019	1327	08/03/1977
WE020	1350	08/03/1977
WE021	1294	08/03/1977
WE022	1197	08/03/1977
WE023	1174	08/03/1977
WE024	1358	08/03/1977
WE025	1450	08/03/1977
WE026	1415	08/03/1977
WE027	1329	08/03/1977
WE028	1438	08/03/1977
WE029	698	08/03/1977
WE030	793	08/03/1977
WE031	1437	08/03/1977
WE032	262	08/04/1977
WE033	1048	08/02/1977
WE034	328	08/02/1977
WE035	907	08/02/1977
WE036	956	08/03/1977
WE037	1017	08/02/1977
WE038	966	08/03/1977
WE039	833	08/02/1977
WE040	833	08/03/1977
WE041	510	08/03/1977
WE042	1168	08/03/1977
WE043	1992	08/03/1977
WE044	1094	08/03/1977
WE045	422	08/03/1977
WE046	512	08/03/1977
WE047	285	08/03/1977
WE048	366	08/02/1977
WE049	87	08/02/1977
WE050	596	08/02/1977
WE051	624	08/03/1977
WE052	442	08/03/1977
WE053	439	08/03/1977
WE054	644	08/03/1977
	314	08/03/1977
	876	08/02/1977

WELL NO	GW STAB. DEPTH CM	GW STAB DATE
WE001	1131	08/03/1977
WE003	1318	08/03/1977
WE005	1316	08/03/1977
WE004	1268	08/03/1977
WE006	77	08/03/1977
WE007	252	08/03/1977
WE008	1263	08/03/1977
WE009	428	08/03/1977
WE010	580	08/03/1977
WE011	1232	08/03/1977
WE012	393	08/03/1977
WE013	1230	08/03/1977
WE014	1264	08/02/1977
WE015	1338	08/03/1977
WE016	1184	08/02/1977
WE017	886	08/03/1977
WE018	1179	08/03/1977
WE019	1327	08/03/1977
WE020	1350	08/03/1977
WE021	1294	08/03/1977
WE022	1199	08/03/1977
WE023	1174	08/03/1977
WE024	1358	08/03/1977
WE025	1430	08/03/1977
WE026	1415	08/03/1977
WE027	1329	08/03/1977
WE028	1436	08/03/1977
WE029	698	08/03/1977
WE030	793	08/03/1977
WE031	1437	08/03/1977
WE032	262	08/04/1977
WE033	1048	08/02/1977
WE034	328	08/02/1977
WE035	907	08/02/1977
WE036	956	08/03/1977
WE037	1017	08/02/1977
WE038	966	08/03/1977
WE039	933	08/02/1977
WE040	510	08/03/1977
WE041	1168	08/03/1977
WE042	992	08/03/1977
WE043	1094	08/03/1977
WE044	422	08/03/1977
WE045	512	08/03/1977
WE046	285	08/03/1977
WE047	368	08/02/1977
WE048	87	08/02/1977
WE049	596	08/02/1977
WE050	624	08/03/1977
WE051	442	08/03/1977
WE052	432	08/03/1977
WE053	644	08/03/1977
WE054	314	08/03/1977
	676	08/02/1977

<u>WELL NO</u>	<u>GW STAB DEPTH CM</u>	<u>GW STAB DATE</u>
WE055	921	08/02/1977
WE056	944	08/02/1977
WE057	785	08/02/1977
WE058	722	08/02/1977
WE059	754	08/02/1977
WE060	329	08/02/1977
WE061	1170	08/02/1977
WE062	189	08/03/1977
WE063	99	08/03/1977
WE064	59	08/03/1977
WE065	646	08/03/1977
WE066	340	08/02/1977
WE067	392	08/02/1977
WE068	471	08/02/1977
WE069	471	08/02/1977
WE070	1000	08/02/1977
WE071	948	08/03/1977
WE072	946	08/03/1977
WE073	1044	08/03/1977
WE074	1208	08/02/1977
WE075	732	08/02/1977
WE076	474	08/02/1977
WE077	437	08/02/1977
WE078	451	08/02/1977
WE079	664	08/02/1977
WE080	387	08/03/1977
WE081	366	08/03/1977
WE082	430	08/03/1977
WE083	261	08/02/1977
WE084	400	08/02/1977
WE085	71	08/02/1977
WE086	443	08/02/1977
WE087	121	08/02/1977
WE088	399	08/02/1977
WE089	623	08/02/1977
WE090	48	08/02/1977
WE091	397	08/02/1977
WE092	494	08/02/1977
WE093	361	08/02/1977
WE094	698	08/04/1977
WE095	143	08/02/1977
WE096	246	08/02/1977
WE097	155	08/03/1977
WE098	825	08/03/1977
WE099	243	08/03/1977
WE100	619	08/03/1977
WE101	495	08/03/1977
WE102	812	08/03/1977
WE103	440	08/03/1977
WE104	398	08/03/1977
WE105	328	08/03/1977
WE106	415	08/03/1977
WE107	759	08/03/1977

WELL NO	GW STAB DEPTH CM	GW STAB DATE
WE001	1120	05/29/1977
WE001	1142	04/09/1977
WE001	1129	07/01/1977
WE003	1308	03/08/1977
WE003	1310	03/07/1977
WE003	1294	05/29/1977
WE003	1310	03/05/1977
WE004	1268	03/15/1977
WE004	1275	04/12/1977
WE004	1263	07/01/1977
WE004	1252	05/29/1977
WE004	1290	03/10/1977
WE005	30	03/11/1977
WE005	63	07/01/1977
WE005	275	05/30/1977
WE005	150	06/01/1977
WE005	85	05/29/1977
WE006	253	05/29/1977
WE006	196	03/12/1977
WE006	263	04/30/1977
WE007	786	03/14/1977
WE007	1458	06/06/1977
WE007	1500	06/28/1977
WE007	1573	05/29/1977
WE007	1259	03/24/1977
WE007	1573	05/29/1977
WE008	411	07/01/1977
WE008	424	03/15/1977
WE008	423	03/17/1977
WE008	421	05/29/1977
WE009	560	05/29/1977
WE009	535	07/01/1977
WE009	563	05/07/1977
WE009	578	03/12/1977
WE010	1215	05/29/1977
WE010	1227	07/01/1977
WE010	1218	03/17/1977
WE011	355	03/19/1977
WE011	383	06/20/1977
WE011	389	07/01/1977
WE011	361	05/29/1977
WE012	1233	06/26/1977
WE012	1245	03/21/1977
WE012	1233	06/28/1977
WE013	1248	05/29/1977
WE013	1272	03/22/1977
WE013	1260	07/01/1977
WE014	1165	03/24/1977
WE014	1252	06/30/1977
WE015	1165	05/29/1977
WE015	1175	07/01/1977
WE016	836	03/26/1977
WE016	870	05/29/1977

WELL NO	GW STAB DEPTH CM	GW STAB DATE
WE017	1130	03/28/1977
WE017	1134	05/29/1977
WE017	1164	07/06/1977
WE018	1310	05/29/1977
WE018	1322	07/02/1977
WE018	1320	03/30/1977
WE018	1311	03/29/1977
WE019	1045	03/30/1977
WE019	1330	07/01/1977
WE019	1322	05/29/1977
WE020	1271	05/29/1977
WE020	1284	03/31/1977
WE020	1288	07/02/1977
WE021	1189	04/01/1977
WE021	1191	07/02/1977
WE021	1176	05/29/1977
WE023	1376	04/05/1977
WE023	1365	06/28/1977
WE023	1366	06/26/1977
WE024	1479	04/05/1977
WE024	1454	06/28/1977
WE025	1413	06/28/1977
WE026	1298	04/07/1977
WE026	1300	06/28/1977
WE026	1298	04/07/1977
WE027	1406	06/28/1977
WE027	1116	04/08/1977
WE027	1406	06/25/1977
WE028	94	04/09/1977
WE028	704	06/28/1977
WE028	700	06/03/1977
WE029	781	06/28/1977
WE029	0	04/09/1977
WE030	1442	04/12/1977
WE030	1433	07/01/1977
WE030	1424	05/29/1977
WE031	114	04/13/1977
WE032	1045	07/01/1977
WE032	1029	05/06/1977
WE032	1034	04/15/1977
WE033	299	04/15/1977
WE033	322	07/01/1977
WE034	1123	07/02/1977
WE034	872	04/16/1977
WE035	949	04/18/1977
WE035	949	04/18/1977
WE035	948	07/02/1977
WE035	947	03/13/1977
WE036	1003	04/20/1977
WE036	1252	07/01/1977
WE036	1012	05/13/1977
WE036	1021	04/19/1977
WE036	1021	04/19/1977
WE037	961	04/23/1977

<u>WELL NO</u>	<u>GW STAB DEPTH CM</u>	<u>GW STAB DATE</u>
WE037	961	04/23/1977
WE037	961	04/23/1977
WE037	961	04/23/1977
WE037	961	07/02/1977
WE038	819	05/27/1977
WE038	825	07/02/1977
WE039	1020	07/02/1977
WE039	1022	04/27/1977
WE039	505	05/30/1977
WE040	1169	07/02/1977
WE040	1170	05/30/1977
WE041	990	04/30/1977
WE041	991	07/02/1977
WE041	990	04/30/1977
WE042	1090	07/02/1977
WE042	713	04/30/1977
WE042	713	04/30/1977
WE042	713	04/30/1977
WE043	396	05/02/1977
WE043	396	05/02/1977
WE043	400	05/31/1977
WE043	410	06/20/1977
WE043	605	04/30/1977
WE043	414	06/28/1977
WE044	506	06/28/1977
WE044	470	05/03/1977
WE044	470	05/03/1977
WE045	300	06/28/1977
WE045	353	06/04/1977
WE046	350	05/06/1977
WE046	361	06/28/1977
WE046	352	06/06/1977
WE046	350	05/06/1977
WE047	359	06/28/1977
WE047	133	05/10/1977
WE047	133	05/10/1977
WE048	559	06/08/1977
WE048	418	05/10/1977
WE048	602	07/01/1977
WE048	418	05/10/1977
WE049	590	06/27/1977
WE049	618	05/09/1977
WE049	618	05/09/1977
WE049	595	05/29/1977
WE050	378	05/10/1977
WE050	378	05/10/1977
WE050	427	07/01/1977
WE051	561	07/01/1977
WE051	640	05/11/1977
WE051	640	05/11/1977
WE051	612	05/29/1977
WE052	527	05/12/1977
WE052	627	05/12/1977
WE053	266	06/06/1977

<u>WELL NO</u>	<u>GW STAB DEPTH CM</u>	<u>GW STAB DATE</u>
WE053	300	06/28/1977
WE053	296	05/31/1977
WE054	870	07/29/1977
WE054	810	05/24/1977
WE055	921	06/30/1977
WE055	768	05/25/1977
WE055	768	05/25/1977
WE056	771	05/26/1977
WE056	771	05/26/1977
WE056	942	06/30/1977
WE057	777	06/30/1977
WE058	721	06/30/1977
WE058	413	05/28/1977
WE058	413	05/28/1977
WE059	733	05/28/1977
WE059	733	05/28/1977
WE059	744	06/30/1977
WE060	268	05/30/1977
WE060	268	05/30/1977
WE060	307	06/30/1977
WE060	288	06/08/1977
WE061	1167	06/13/1977
WE061	1168	06/27/1977
WE061	1179	05/31/1977
WE061	1168	06/08/1977
WE061	1179	05/31/1977
WE062	175	06/28/1977
WE062	151	06/01/1977
WE062	151	06/01/1977
WE063	195	06/02/1977
WE063	105	06/28/1977
WE063	95	06/02/1977
WE064	58	06/03/1977
WE064	71	06/28/1977
WE064	58	06/03/1977
WE065	647	06/30/1977
WE066	324	06/28/1977
WE066	329	06/06/1977
WE066	329	06/06/1977
WE067	382	06/28/1977
WE068	505	06/08/1977
WE068	505	06/08/1977
WE068	469	06/24/1977
WE068	469	06/28/1977
WE069	996	06/13/1977
WE069	996	06/13/1977
WE069	998	06/30/1977
WE070	944	06/11/1977
WE070	949	07/01/1977
WE070	944	06/11/1977
WE071	881	06/11/1977
WE071	881	06/11/1977
WE072	1041	07/01/1977
WE072	1039	06/13/1977

<u>WELL NO</u>	<u>GW STAB DEPTH CM</u>	<u>GW STAB DATE</u>
WE072	1039	06/13/1977
WE073	1213	06/14/1977
WE073	1208	06/30/1977
WE073	1213	06/14/1977
WE074	1239	06/15/1977
WE074	728	06/30/1977
WE074	1239	06/15/1977
WE075	470	06/16/1977
WE075	470	06/16/1977
WE075	473	06/18/1977
WE075	472	06/30/1977
WE076	433	06/18/1977
WE076	245	06/17/1977
WE076	245	06/17/1977
WE076	434	06/30/1977
WE076	433	06/18/1977
WE077	472	06/18/1977
WE077	472	06/18/1977
WE077	458	06/30/1977
WE078	724	06/20/1977
WE078	561	06/27/1977
WE078	652	07/02/1977
WE078	724	06/20/1977
WE078	948	07/29/1977
WE079	378	07/01/1977
WE079	377	06/21/1977
WE079	377	06/21/1977
WE080	390	06/22/1977
WE080	388	06/28/1977
WE080	390	06/22/1977
WE081	478	06/23/1977
WE082	280	07/04/1977
WE082	280	07/04/1977
WE083	400	07/06/1977
WE083	400	07/05/1977
WE083	81	07/06/1977
WE084	81	07/06/1977
WE085	438	07/07/1977
WE085	438	07/07/1977
WE086	147	07/08/1977
WE086	147	07/08/1977
WE087	381	07/09/1977
WE087	381	07/09/1977
WE088	622	07/09/1977
WE088	622	07/09/1977
WE089	41	07/11/1977
WE089	41	07/11/1977
WE090	380	07/11/1977
WE091	494	07/13/1977
WE092	363	07/13/1977
WE093	689	07/15/1977
WE096	155	07/16/1977

WELL NO	GW STAB DEPTH CM	CW STAB DATE
WE097	821	07/18/1977
WE098	244	07/20/1977
WE099	562	07/20/1977
WE099	620	07/21/1977
WE100	470	07/22/1977
WE100	491	07/23/1977
WE100	497	07/25/1977
WE101	570	07/23/1977
WE101	572	07/25/1977
WE102	410	07/23/1977
WE102	412	07/23/1977
WE102	510	07/23/1977
WE102	424	07/25/1977
WE103	387	07/25/1977
WE103	530	07/25/1977
WE103	386	07/25/1977
WE103	387	07/25/1977
WE104	320	07/25/1977
WE104	422	07/25/1977
WE104	316	07/26/1977
WE105	414	07/27/1977
WE105	414	07/27/1977
WE106	667	07/28/1977
WE106	668	07/29/1977
WE107	758	07/29/1977

APPENDIX B: LABORATORY SOIL TEST PROCEDURES

Physical Test

Standard soil test procedures as specified by Engineer Manual 1110-2-1906, "Laboratory Soil Testing," were followed during testing.

Unified Soil Classification System

Classification of soils according to the USCS depends upon grain-size distribution and the Atterberg limits. Grain-size distribution is determined with sieves and a hydrometer, and the liquidity and plasticity (Atterberg limits) are determined with standard devices. The liquid and plastic limits are the water contents at the boundaries between the semiliquid and plastic state and the plastic and semisolid state, respectively. Figure B1 shows the USCS by which the PBA soil samples were described. Figures B2-B7 present the laboratory data sheets for the classification of two samples; one a coarse-grained material (SP-SM) and the other a fine-grained material (CL).

Water Content and Density

Water content and soil density are important engineering relationships and are useful correlations among samples for which a full suite of physical test data are not available. Water content is the amount of free water in a soil and is determined to the following formula:

$$W = \frac{W_w}{W_s}$$

where W = water content

W_w = weight of water

W_s = dry weight of soil

Density or dry unit weight is determined according to the following formula:

$$D = \frac{W_s}{V}$$

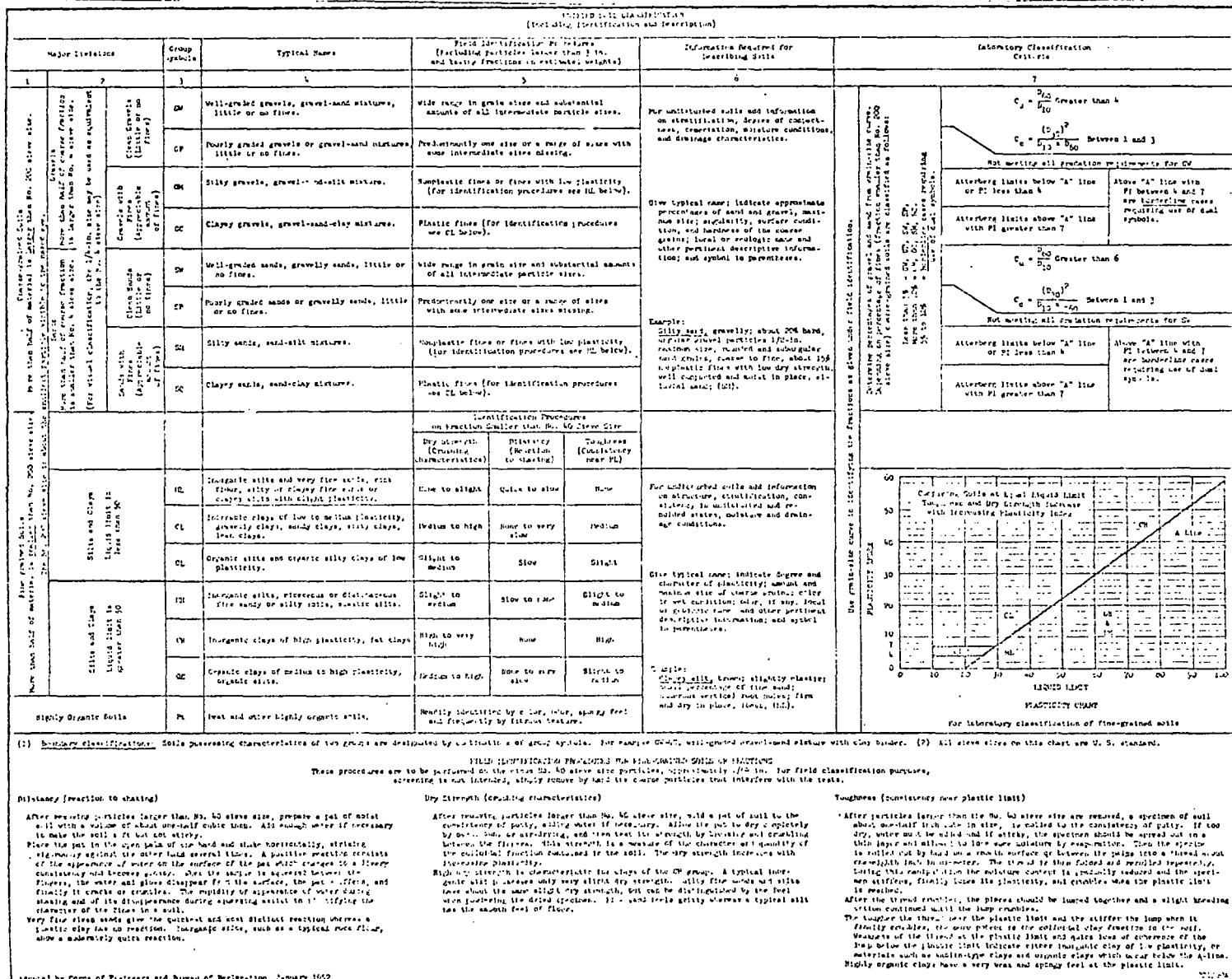


Figure B1. Unified Soil Classification System

SIEVE ANALYSIS								
Date 9 JAN 78								
Project Price Bluff Arsenal								
Boring No. 01		Sample No. 7 (1419-1500 cm)						
Total wt. in grams of sample, W _s =		Wt. in grams of material > No. 4 sieve =						
Sieve Openings	U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained		Percent Finer by Weight			
Inches	Millimeters		Partial	Total				
3.00		3-in.						
2.00		2-in.						
1.50		1-1/2-in.						
1.00	25.4	1-in.						
0.750	19.1	3/4-in.						
0.500	12.7	1/2-in.						
0.375	9.52	3/8-in.						
0.250	6.35	No. 3						
0.187	4.76	No. 4						
Pan								
0.132	3.35	No. 6	0.3	0.2	99.8			
0.094	2.35	No. 8	-	-	-			
0.072	2.00	No. 10	0.7	0.5	99.5			
0.047	1.10	No. 16	1.0	0.7	99.3			
0.033	0.84	No. 20	1.2	0.9	99.1			
0.023	0.50	No. 30	1.4	1.0	99.0			
0.0165	0.42	No. 40	1.6	1.2	98.8			
0.0117	0.297	No. 50	2.3	1.7	98.3			
0.0083	0.210	No. 70	13.3	9.6	90.4			
0.0059	0.149	No. 100	72.8	52.6	47.2			
0.0041	0.105	No. 140	115.4	83.7	16.3			
0.0039	0.074	No. 200	129.8	94.1	5.9			
Pan								
Total weight in grams 137.9								
Partial percent retained = $\frac{wt \text{ in grams retained on a sieve}}{wt \text{ in grams of sample used for a given series of sieves}} \times 100$								
Total percent retained = $\frac{wt \text{ in grams retained on a sieve}}{total wt \text{ in grams of oven-dry sample}} \times 100$								
For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve								
Resarks Fines Not Plastic (SPSM) Tan								
Technician <u>R.E.</u>	Computed by <u>R.E.</u>	Checked by <u>K.R.</u>						
E&G FORM 3841								
PLATE V-1								

Figure B2. Sieve analysis for boring No. 1, sample No. 7

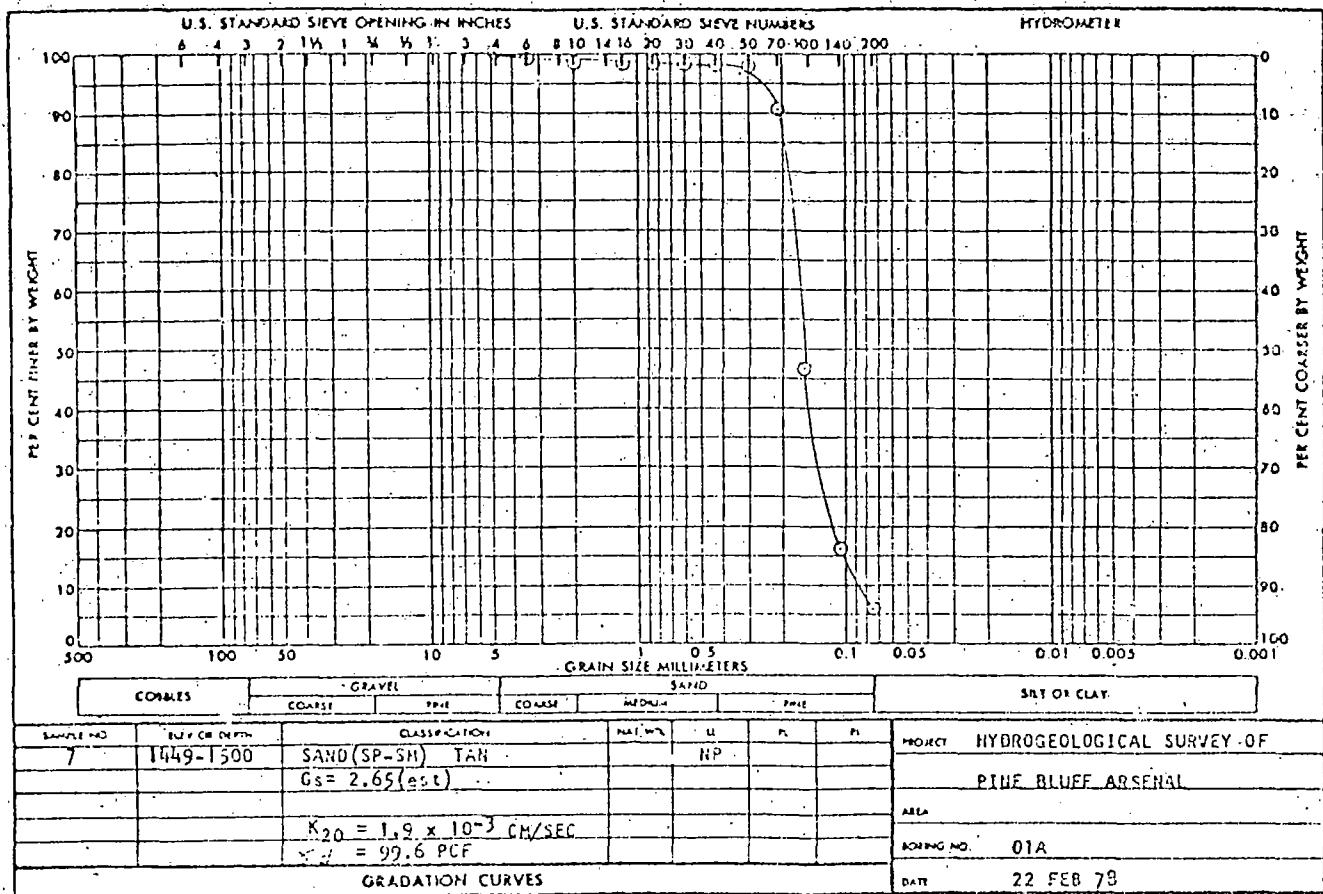


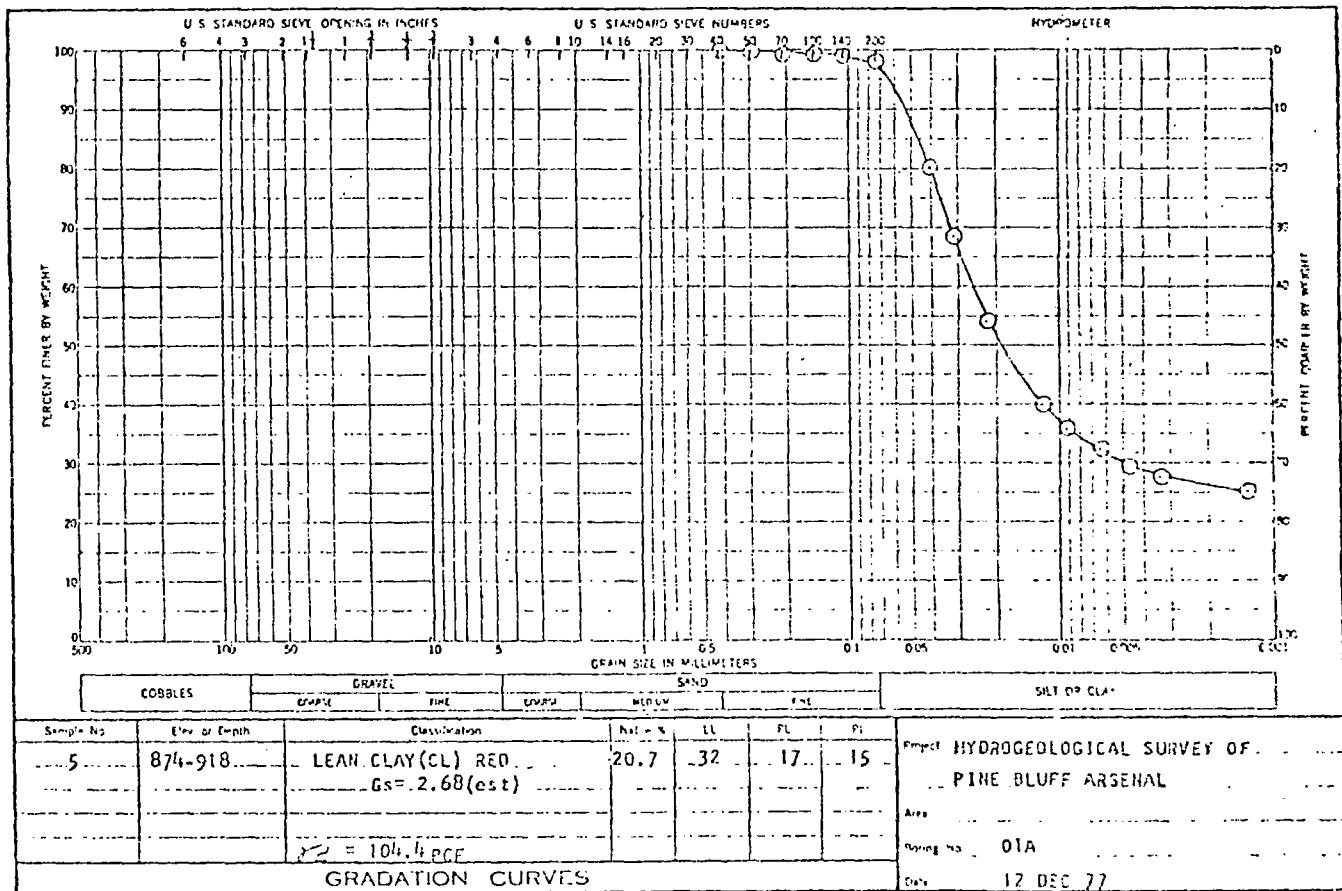
Figure B3. Grain size distribution for boring No. 1, sample No. 7

Sieve Analysis					
Project Blue Bluff Arsenal Hydrogeological Survey					
Boring No. 01		Sample No. 5 (874-916 cm)			
		Total wt in grams of sample, W =			
		Wt in grams of material > No. 4 sieve =			
Sieve Openings		U. S. Standard Sieve Size or Number	Weight Retained in grams	Percent Retained	
Inches	Millimeters			Partial	Total
3.00		3-in.			
2.00		2-in.			
1.50		1-1/2-in.			
1.00	25.4	1-in.			
0.750	19.1	3/4-in.			
0.500	12.7	1/2-in.			
0.375	9.52	3/8-in.			
0.250	6.35	No. 3			
0.187	4.76	No. 4			
Pan					
0.132	3.35	No. 6			
0.064	2.38	No. 8			
0.070	2.00	No. 10			
0.047	1.19	No. 16			
0.033	0.84	No. 20			
0.022	0.59	No. 30			
0.0155	0.42	No. 40			100
0.0117	0.297	No. 50	0.1		99.8
0.0093	0.210	No. 70	0.2		99.7
0.0059	0.149	No. 100	0.3		99.5
0.0011	0.105	No. 140	0.4		99.3
0.0029	0.074	No. 200	1.0		98.3
Pan					
Total weight in grams					
Partial percent retained = $\frac{wt \text{ in grams retained on a sieve}}{wt \text{ in grams of sample used for a given series of sieves}} \times 100$					
Total percent retained = $\frac{wt \text{ in grams retained on a sieve}}{total wt \text{ in grams of oven-dry sample}} \times 100$					
For an individual sieve, the percent finer by weight = percent finer than next larger sieve - percent retained on individual sieve					
Remarks					
Technician <u>R.E.</u>		Computed by <u>R.E.</u>	Checked by <u>K.R.</u>		
EBC FORM 100-6 3841		PLATE V-1			

Figure B4. Sieve Analysis for boring No. 1, sample No. 5

HYDROMETER ANALYSIS							
Project: Pine Bluff Arsenal Hydrogeological Survey Boring No. 1 Sample No. 5 (874-918 cm) Classification: CL							
Date: 20 Nov 77							
Dish No. M-22		Graduate No.		Hydrometer No.			
Dissipate agent used: Sod Test		Quantity 60 cc					
Dissipate agent correction, C_d		Minimatic correction, C_m					
Time min	Elapsed Time min	Temp °C	Hydro- meter Reading (R')	Corrected Reading (R)	Particle Diameter (D), mm	Temp Correc- tion (n)	Percent Finer Partial Total
	1	3.0	30.0	30.5	0.041	30.1	80.0
	2	25.8	26.3	0.031		25.9	48.9
	4	20.2	20.7	0.023		20.3	54.0
	15	14.9	15.4	0.0129		15.0	40.0
	30	13.4	13.9	0.0092		13.5	35.9
	60	4.0	12.0	12.5	0.0066	12.3	32.7
	120	1.0	10.8	11.3	0.0048	11.1	29.5
	240	5.0	10.0	10.5	0.0034	10.5	27.5
	1640	3.0	9.4	9.9	0.0014	9.5	25.3
Weight in grams	Dish plus dry soil			Specific gravity of solids, $G_s = 2.68$ est.			
	Dish						
	Dry soil 60.0	%	Corrected hydrometer reading (R) = hydrometer reading (R') + C_m				
The particle diameter (D) is calculated from Stoke's equation using corrected hydrometer reading. Use nomographic chart for solution of Stoke's equation.							
Hydrometer graduated in specific gravity				W_s = total oven-dry wt of sample used for combined analysis			
$\text{Partial percent finer} = \frac{G_s}{G_s - 1} \times \frac{100}{W_0} (R - C_d + n)$				W_0 = oven-dry wt in grams of soil used for hydrometer analysis			
Hydrometer graduated in grams per liter				W_1 = oven-dry wt of sample retained on No. 200 sieve			
$\text{Partial percent finer} = \frac{10^3}{W_0} (R - C_d + n)$							
Total percent finer = partial percent finer $\times \frac{W_s - W_1}{W_s}$							
Remarks _____							
Technician: R.C.		Computed by: R.C.		Checked by: K.R.			
ENG FORK 3842				D41495 PLATE V-3			

Figure B5. Hydrometer analysis for boring No. 1, sample No. 5



ENG FORM 2087

Figure B6. Grain size distribution for boring No. 1, sample No. 5

LIQUID AND PLASTIC LIMIT TESTS For use of this form, see EM 1110-21006						
PROJECT <u>Pine Hill, NC Hydrogeological Survey</u>		DATE <u>10-21-67</u>				
BOREH NO. <u>01</u>		SAMPLE NO. <u>5 (F74 - 41R cm)</u>				
LIQUID LIMIT						
HUN NO.	1	2	3	4	5	6
TARE NO.	11	13	15	17		
TARE PLUS WET SOIL	40.98	59.63	59.46	62.36		
TARE PLUS DRY SOIL	54.69	53.89	53.87	56.36		
WATER	W ₁	5.74	5.59	6.00		
TARE	36.39	36.19	36.06	36.74		
DRY SOIL	W ₂	18.70	17.17	17.61	19.57	
WATER CONTENT, %	W	34.4	33.4	31.4	30.7	
NUMBER OF BLOWS	14	22	24	35		
<p>WATER CONTENT, w (%)</p> <p>NUMBER OF BLOWS</p> <p>LL = 32.0</p> <p>PL = 17.0</p> <p>PI = 15.0</p> <p>Symbol from plasticity chart: CL</p>						
PLASTIC LIMIT						
HUN NO.	1	2	3	4	5	NATURAL WATER CONTENT
TARE NO.	57	58				
TARE PLUS WET SOIL	46.34	46.08				
TARE PLUS DRY SOIL	44.94	44.75				
WATER	W ₁	1.20	1.37			
TARE	36.75	37.12				
DRY SOIL	W ₂	9.22	7.67			
WATER CONTENT, %	W	17.0	17.4			
PLASTIC LIMIT	172					
REMARKS	<u>S.1/4 C1/2 (CL), LF Red</u>					
TECHNICIAN: <u>R.D.</u>	COMPUTED BY <u>J.B.D.</u>			CHECKED BY <u>K.R.</u>		

ENG FORM 3839
1 JUN 65

Figure B7. Liquid and plastic limits for boring No. 1,
sample No. 5

where D = density

w_s = dry weight of soil

V = volume of soil

Permeability

Permeability is a measure of a soil's ability to transmit a fluid; in the current study the fluid is water. The flow of water through a soil is governed by Darcy's law:

$$q = Kia$$

where q = rate of discharge through a soil of cross-sectional area A

k = coefficient of permeability.

i = hydraulic gradient (the loss of hydraulic head per unit distance of flow)

A = sample area perpendicular to flow

For coarse-grained materials, permeability tests are usually conducted in a constant head apparatus. In this equipment, an overflowing reservoir maintains a constant head on a soil sample of specified dimensions and the amount of water passing through the soil in a specified time is collected and measured. The permeability is then calculated according to the formula:

$$k_{20} = \frac{QLR_t}{hAt}$$

where k_{20} = coefficient of permeability, cm/sec at 20°

Q = quantity of flow, cc

L = length of specimen over which head loss is measured, cm.

If piezometer taps are used, L is equal to the distance between piezometer taps.

R_t = temperature correction factor for viscosity of water

h = head loss across sample or between piezometer taps, cm

A = cross-sectional area of specimen, sq cm

t = elapsed time, sec

Figure B8 is a schematic representation of the testing apparatus and Figure B9 is the data set from boring No. 8, sample No. 5.

Permeability tests for fine-grained soils are usually performed on confined specimens which permit an increase of pressure, thus decreasing gas volume and increasing saturation. The head is allowed to fall during the test, and permeability is calculated according to the formula:

$$K_{20} = \frac{2.303 aLR_t \log \frac{h_0}{h_f}}{At}$$

where K_{20} = coefficient of permeability, cm/sec at 20°C

a = inside area of standpipe, sq cm

A = cross-sectional area of specimen, sq cm

L = length of specimen, cm

t = elapsed time ($t_f - t_0$), sec

h_0 = height of water in standpipe above discharge level at time t_0 , cm

h_f = height of water in standpipe above discharge level at time T_f , cm

R_t = temperature correction factor for viscosity of water

Figure B10 is a schematic representation of the testing apparatus and

Figure B11 is the data set from boring No. 12, sample No. 2.

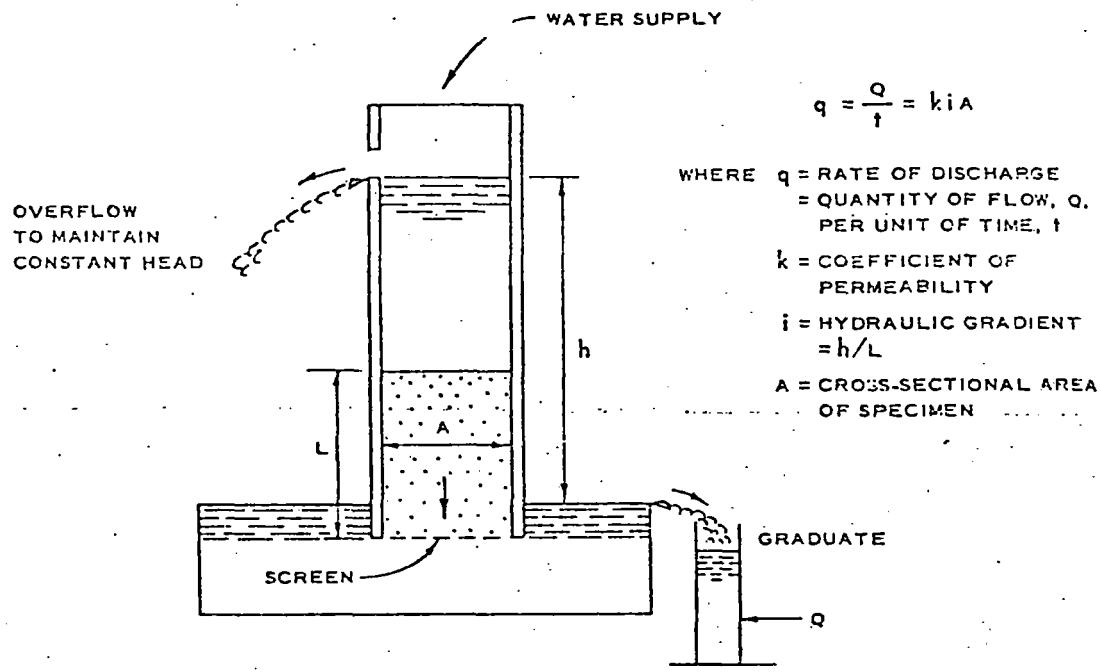
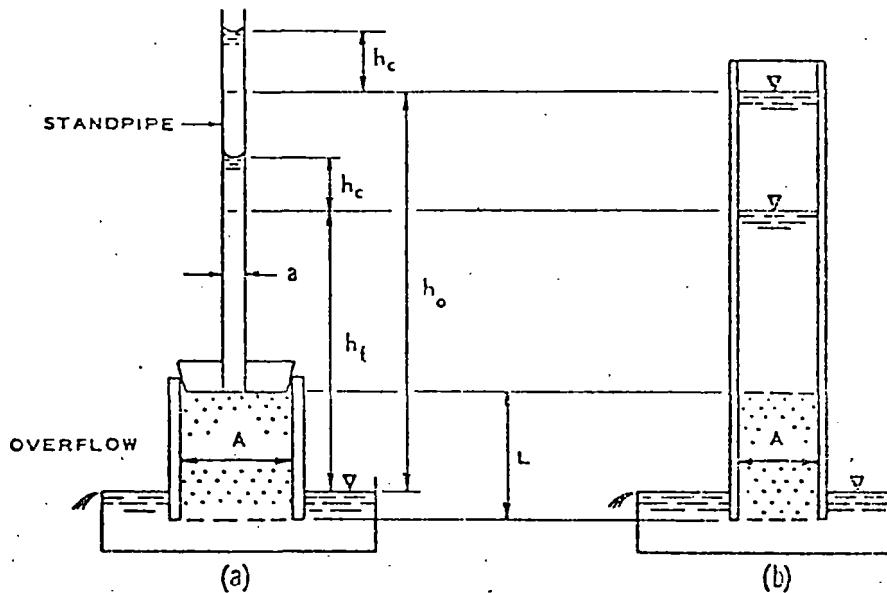


Figure B8. Schematic representation of constant head testing apparatus

Constant Head Permeability Test																																																																					
Date 27 June 78																																																																					
Project Pine Bluff Ground Hydrogeological Survey																																																																					
Boring No. 8																																																																					
Sample or Specimen No. 5																																																																					
in cm	Tare plus dry soil	411.55	Diameter of specimen, cm	6	71.88																																																																
	Tare	51.70	Amt of specimen, sq cm	5	20.583																																																																
	Dry soil	359.85	Initial height of specimen, cm	2	5.651																																																																
Specific gravity	G	2.65, est	Initial vol of spec, cc = AL	V	329.334																																																																
Vol of solution, cc = $W_p + \frac{1}{3}V_s$	135.792	Initial void ratio = $(V - V_s)/V_s$	e	0.689																																																																	
Distance between piezometer taps, cm																																																																					
<table border="1"> <thead> <tr> <th>Test No.</th> <th>1</th> <th>2</th> <th>3</th> </tr> </thead> <tbody> <tr> <td>Height of specimen, cm</td> <td>L</td> <td>5.651</td> <td>5.651</td> <td>5.651</td> </tr> <tr> <td>Void ratio = $(AL - V_s)/V_s$</td> <td>e</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td>2s</td> <td>2t</td> <td>2u</td> <td>2v</td> </tr> <tr> <td>Pending of piez 1, cm</td> <td>z_1</td> <td>5.4</td> <td>5.4</td> <td>5.4</td> </tr> <tr> <td>Pending of piez 2, cm</td> <td>z_2</td> <td>4.0</td> <td>4.0</td> <td>4.0</td> </tr> <tr> <td>Head loss, cm = $h_1 - h_2$</td> <td>h</td> <td>1.4</td> <td>1.4</td> <td>1.4</td> </tr> <tr> <td>Quantity of flow, cc</td> <td>Q</td> <td>10.0</td> <td>10.0</td> <td>10.0</td> </tr> <tr> <td>Elapsed time, sec</td> <td>t</td> <td>42</td> <td>46</td> <td>47</td> </tr> <tr> <td>Water temperature, °C</td> <td>T</td> <td>24.4</td> <td>24.4</td> <td>24.4</td> </tr> <tr> <td>Viscosity correction factor⁽¹⁾</td> <td>R_T</td> <td>0.961</td> <td>0.961</td> <td>0.961</td> </tr> <tr> <td>Coefficient of permeability⁽²⁾, cm/sec</td> <td>k_{20}</td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td>Avg</td> <td>2.13×10^{-2}</td> <td>1.95×10^{-2}</td> <td>1.91×10^{-2}</td> </tr> </tbody> </table>						Test No.	1	2	3	Height of specimen, cm	L	5.651	5.651	5.651	Void ratio = $(AL - V_s)/V_s$	e					2s	2t	2u	2v	Pending of piez 1, cm	z_1	5.4	5.4	5.4	Pending of piez 2, cm	z_2	4.0	4.0	4.0	Head loss, cm = $h_1 - h_2$	h	1.4	1.4	1.4	Quantity of flow, cc	Q	10.0	10.0	10.0	Elapsed time, sec	t	42	46	47	Water temperature, °C	T	24.4	24.4	24.4	Viscosity correction factor ⁽¹⁾	R _T	0.961	0.961	0.961	Coefficient of permeability ⁽²⁾ , cm/sec	k_{20}					Avg	2.13×10^{-2}	1.95×10^{-2}	1.91×10^{-2}
Test No.	1	2	3																																																																		
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(1) Correction factor for viscosity of water at 20°C obtained from table VII-1. $Q \times L \times R_T$																																																																					
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Remarks _____																																																																					
Technician R.E. Computed by R.E. Checked by K.R.																																																																					

Figure B9 Constant head permeability data for boring No. 8, sample No. 5



USING SETUP SHOWN IN (a), THE COEFFICIENT OF PERMEABILITY IS DETERMINED AS FOLLOWS:

$$k = \frac{L a}{A t} \ln \frac{h_o}{h_f} = 2.303 \frac{L a}{A t} \log_{10} \frac{h_o}{h_f}$$

USING SETUP SHOWN IN (b), THE COEFFICIENT OF PERMEABILITY IS DETERMINED AS FOLLOWS:

$$k = \frac{L}{t} \ln \frac{h_o}{h_f} = 2.303 \frac{L}{t} \log_{10} \frac{h_o}{h_f}$$

WHERE: h_c = HEIGHT OF CAPILLARY RISE
 a = INSIDE AREA OF STANDPIPE
 A = CROSS-SECTIONAL AREA OF SPECIMEN
 L = LENGTH OF SPECIMEN
 h_o = HEIGHT OF WATER IN STANDPIPE ABOVE DISCHARGE LEVEL MINUS h_c AT TIME, t_o
 h_f = HEIGHT OF WATER IN STANDPIPE ABOVE DISCHARGE LEVEL MINUS h_c AT TIME, t_f
 t = ELAPSED TIME, $t_f - t_o$

Figure B10. Schematic representation of falling head testing apparatus